SKY WARS

ADVANCES IN TECHNOLOGY are changing the face of aerial warfare. The original American F-15, for example, was designed as a fighter aircraft, but now, it has been turned into a bomber as well.

The F-15E Eagle long-range strike fighter carries extra fuel in tanks, which are shaped to fit the sides of the fuselage. Bombs are carried one behind another, so that the slip-stream from the first bomb covers the second to reduce air resistance. Previous aircraft have given away their position by emitting radar signals that can be tracked by an enemy. Once close to its target, the F-15E can shut down its radar and navigate by an infra-red thermal image system.

The General Dynamics F-16XL design for the 1990s has an innovative 'cranked-arrow' wing, which acts as two wings in one. The inner section is similar to the conventional delta wing, found on a Vulcan bomber, but the outer, thin part

***Fighter aircraft** are frequently modified to improve their performance and to incorporate countermeasures against new weapons and detection systems. Improvements were made to the F-15's radar, computer and electronics systems.*

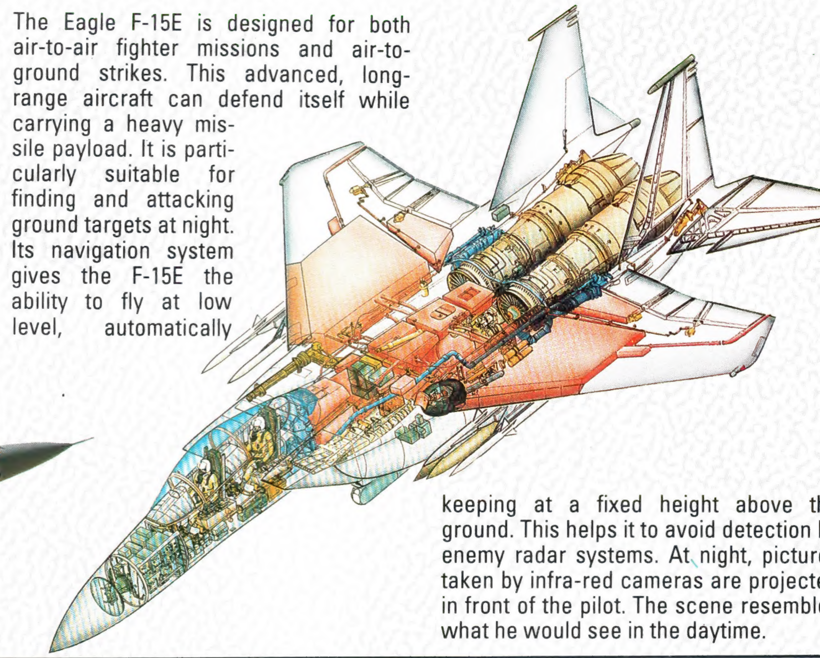
***Flight simulators** are used to test the controls and displays of an aircraft. The pilot has information projected on to a glass screen in front of him, so he can still see out of the F-15E's cockpit while reading his instruments.*

McDonnell Douglas Corporation

gives extra room for pitch and roll control surfaces. This makes the F-16XL highly manoeuvrable.

Cranked-arrow wings undergo complex stresses and rely on carbon fibre composite materials for their construction. The wing contains millions of tiny carbon fibres, held together with an epoxy resin. If the fibres are parallel, the wing will be stiffer in one direction than another. Unlike metal wings, carbon fibre wings can be designed to bend easily in some directions, but be very rigid in others. This technique is called 'aero-elastic tailoring'.

DUAL-ROLE FIGHTER



The Eagle F-15E is designed for both air-to-air fighter missions and air-to-ground strikes. This advanced, long-range aircraft can defend itself while carrying a heavy missile payload. It is particularly suitable for finding and attacking ground targets at night. Its navigation system gives the F-15E the ability to fly at low level, automatically keeping at a fixed height above the ground. This helps it to avoid detection by enemy radar systems. At night, pictures taken by infra-red cameras are projected in front of the pilot. The scene resembles what he would see in the daytime.

McDonnell Douglas Corporation

MISSILE FILE

General Dynamics

Missiles can be classified according to the role they perform. Air-to-surface missiles are carried by aircraft and used to attack targets on the ground. They can be guided by laser or radar. Surface-to-air missiles defend against airborne attack, as the British Aerospace Rapier demonstrated during the Falklands campaign in 1982. The F-16 (above) carries missiles for attacking both air and ground targets.

The American Aegis missile system can detect incoming aircraft and destroy them before visual contact is made. This was tragically demonstrated in July 1988, when the Aegis-fitted warship USS *Vincennes* accidentally shot down an Iran Air A300 Airbus.

The French-built Exocet is probably the best-known anti-ship missile. Other classes of missile include anti-submarine and anti-tank missiles.

Strategic missiles include long-range as well as intermediate-range nuclear weapons. The US Ground Launched Cruise Missile (GLCM) has a nuclear warhead. GLCMs were deployed at RAF Greenham Common in December 1983, but have since been withdrawn. Russian strategic missiles comprise the SS series of weapon. The SS-20 missile entered service in 1977.

A United States Air Force proposal for the mid-1990s is the Advanced Tactical Fighter (ATF). ATF will fulfill a dual-mission fighter/attack role. The aircraft will be able to cruise and manoeuvre supersonically at an altitude of 20 km and beyond. ATF may be fitted with a forward-swept wing, which was tested on the Grumman X-29A research plane.

Short runways

ATF will be able to take off and land on very short runways, which will enable it to operate from bomb-damaged airfields. The target runway requirement is about 450 metres, which is one-sixth of the standard NATO (North Atlantic Treaty Organization) runway length.

Short take-off and landing (STOL) from a runway measuring just a few hundred metres long is already possible with some aircraft in current production. This capability is likely to become a standard requirement for the NATO warplanes of the early 21st century.

Another aircraft of the future is the advanced short take-off/vertical landing (ASTVOL) fighter. Various proposals have been put forward, including one for a six-engined fighter. This will have four engines in swivelling pods on the wingtips, with another two fitted vertically in the fuselage. ASTVOL aircraft may replace the F-16 and Harrier II designs by the turn of the century.

The replacements for the successful Lockheed SR-71 Blackbird strategic reconnaissance aircraft will probably be flying by the year 2000. This may be capable of speeds around 6,500 km/h at an altitude of 35-40 km. Such an aircraft would be powered by supersonic-combustion scramjets. The engines will burn liquid hydrogen, which would also be used to cool the airframe. In-flight refuelling with liquid hydrogen may well prove to be impossible, however, which would limit the new aircraft's range.

General Dynamics

Manoeuvrability *is an important feature of today's fighter aircraft. Because of its tight turning ability, the F-16's structure has been specially designed to withstand the extremely high stresses produced.*

Paul Raymonde

FLIGHT 2000

Q INVISIBLE PLANES

Q VOICE CONTROL

Q EJECTOR SEATS


Kaiser

The future of flight – the film Firefox foresaw developments that have become a reality. The new Agile Eye helmet uses a cathode ray tube to relay information to the pilot wherever he moves his head.

FUTURE JET ENGINES WILL produce a thrust of over ten times their own weight. They will therefore be more than three times as powerful as early jet engines.

Materials lighter than metal will have to be used in their manufacture to help achieve such improvement in engine performance. Some of the most promising new engine materials are ceramics, such as silicon nitride and silicon carbide. They are stronger than metals, but only half as dense as the alloys they are destined to replace.

Engine manufacturers Pratt and Whitney are working on a combined carbon fibre and ceramic material called 'Compglas', which has already been successfully tested in aero engines. The engines of the future may even produce thrust to weight ratios of 15:1 – nearly five times as good as their early predecessors. New materials will also have an important role to play in airframes as well as engines.

Vehicles that fly at high speed can become very hot owing to friction with the air. The new materials, therefore, need to be both light and able to withstand high temperatures. One possibility being studied is a carbon-ceramic matrix. This would comprise carbon fibres embedded in silicon carbide.

Stealth technology

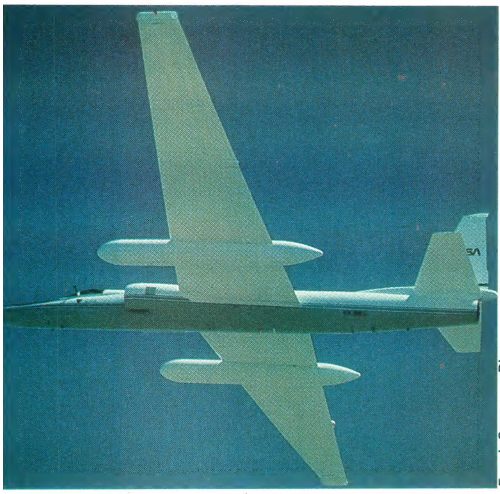
Another area where new technology is coming to the fore is the so-called Stealth aircraft. The best way to avoid a fighter aircraft being shot down is to make it invisible. This was done in the early days of aviation by painting planes with camouflage patterns, but fancy paintwork is not much use to a modern fighter pilot.

Nowadays, pilots may find themselves in combat with other aircraft they cannot even see. It is possible to be shot down without ever seeing the aircraft that fired. Modern warfare relies on radar to detect potential enemy targets. To make an aircraft invisible, it has to be made invisible to radar. That is where Stealth technology comes in.

One way to modify an aircraft's 'radar signature' is to change its shape. Thin, flat aircraft reflect much less radar energy than thicker, conventional designs. The ideal Stealth aircraft would resemble a

Warner Bros/Kobal Collection

flying pancake and present a very small cross-sectional area to a radar beam. Other steps can be taken to reduce the amount of radar energy that is reflected. For example, anti-radar paints, which are poor reflectors of radar signals, can be used to cover the airframe.



Frank Spooner Pictures

***The Lockheed ER-2** was purpose-built for NASA (the National Aeronautics and Space Administration). It is the prototype of the TR-1 spyplane.*

There are further steps that can be taken to render an aircraft undetectable. Emissions of sound, smoke trails, infra-red (heat) radiation and radio waves have to be minimized as well.

Race against time

Forty years ago, an enemy plane that was 30 km away would take a couple of minutes to come into view. In that time a pilot would be able to check his position, his weapons systems and get ready for the ensuing battle. Nowadays an enemy plane travels at such speed that it would cover the 30 km in under 30 seconds, allowing the pilot very little time to prepare for combat.

Researchers have been exploring ways of taking some of the workload away from the pilot, and making the controls quicker and easier to use. Computers will navigate the plane, control the engines, and remind the pilot of any necessary course of action.

The cockpit

Most up-to-date fighter aircraft are already fitted with Head Up Displays (HUD), which allow the pilot to check the main instruments and the radar display without looking down into the cockpit. But the image on a HUD appears to be quite close to the pilot, so he still has to re-focus his eyes from instruments to target and back again.

The aircraft of the future will

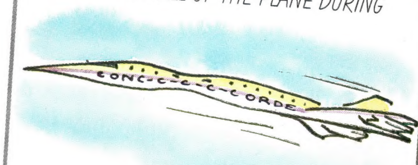
United Technologies

***Gas turbine engine** components made from compglas have proved to be exceptionally strong and stable at high temperatures.*

Just amazing!

SUPERSONIC LIBRARY

DURING SUPERSONIC FLIGHT, CONCORDE GROWS UP TO 25 CM LONGER. WHEN A CREW MEMBER SLOTTED A BOOK INTO A GAP IN THE WALL OF THE PLANE DURING



A FLIGHT HE WAS SURPRISED TO FIND THAT ON LANDING THE GAP HAD DISAPPEARED AND SO HAD THE BOOK. THE BOOK REAPPEARED ON THE NEXT SUPERSONIC FLIGHT WHEN THE GAP OPENED UP AGAIN.

Paul Raymonde

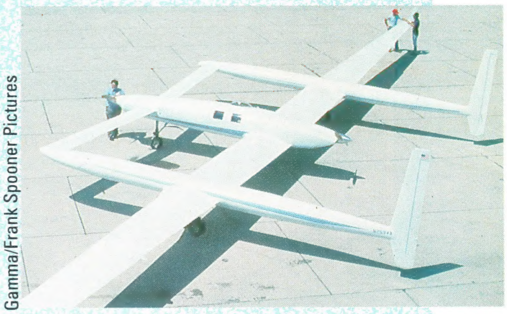
AROUND THE WORLD IN NINE DAYS

Dick Rutan and Jeana Yeager flew non-stop around the world without refuelling in their specially constructed *Voyager* aircraft. They left Edwards Air Force Base in California, USA, on 14 December 1986, returning on 23 December. The total duration of the flight was 9 days, 3 minutes and 44 seconds. *Voyager* had flown for 40,253 km at an average speed of 186 km/h.

The pilot flew the plane from a cockpit measuring 1.7 × 0.54 metres and the other crew member rested in a space measuring 2.3 × 0.6 metres.

Voyager was designed by Dick Rutan's brother, Burt, who first sketched his ideas on the back of a paper napkin in a restaurant. The aircraft was constructed using many novel lightweight materials, including graphite and paper.

It has a wing span of 33.77 metres and can carry 5,636 litres of fuel weighing 4,052 kg. The aircraft took more than two years and 22,000 man-hours to build.



Gamma/Frank Spooner Pictures

ESCAPING DEATH

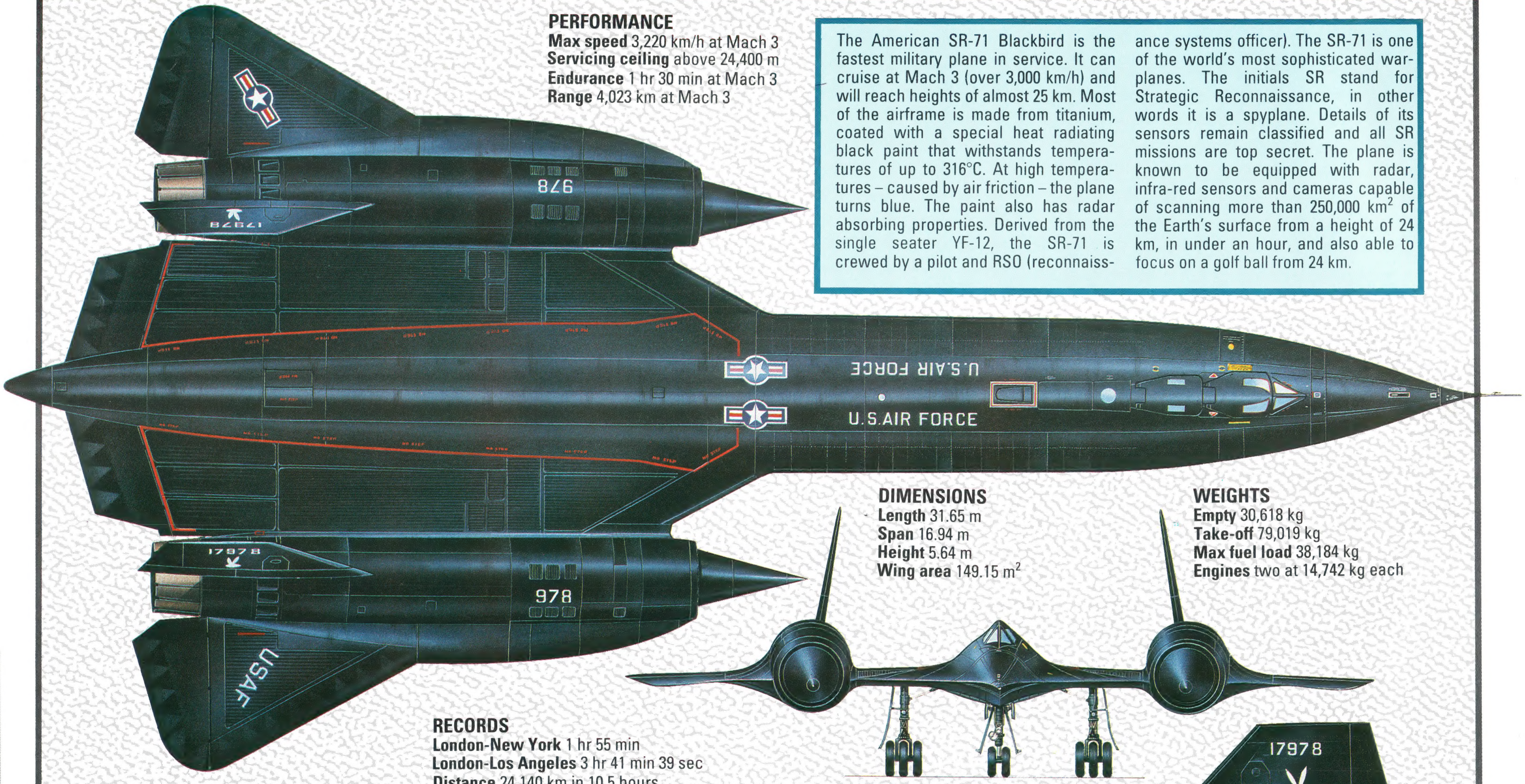
With the introduction of jet-powered aircraft, the possibility of a successful 'over the sides' bale out was virtually eliminated. Thus the forced ejection of a pilot became a necessity.

The most effective ejection seat currently in use is the Advanced Concept Ejection Seat II (ACES). In the last ten years, ACES II has saved the lives of more than ten pilots.

To trigger the ejection sequence, the pilot must pull his face cover over his head. At this point thin strands of explosive shatter the canopy. This is followed by a series of small charges, which push the seat clear of the cockpit. Once the seat is free, a booster rocket propels the seat for a few hundred metres from the aircraft. At this point, the seat automatically unstraps the pilot, leaving him free to parachute safely to the ground.

Today's seats are a long way from the days when a pilot had to unstrap himself from the seat and then release his parachute. In those days, many a pilot fell to the ground and died, still strapped to his seat.

McDonnell Douglas Corporation



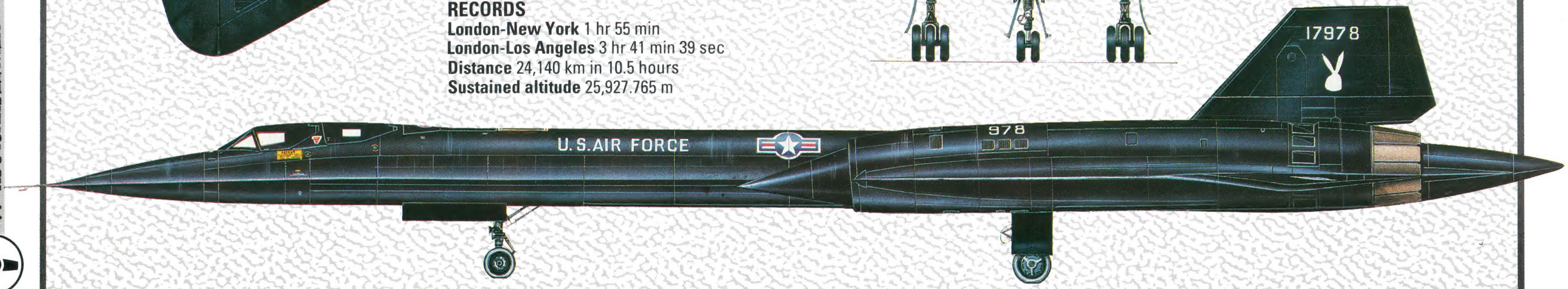
The American SR-71 Blackbird is the fastest military plane in service. It can cruise at Mach 3 (over 3,000 km/h) and will reach heights of almost 25 km. Most of the airframe is made from titanium, coated with a special heat radiating black paint that withstands temperatures of up to 316°C. At high temperatures – caused by air friction – the plane turns blue. The paint also has radar absorbing properties. Derived from the single seater YF-12, the SR-71 is crewed by a pilot and RSO (reconnaissance systems officer). The SR-71 is one of the world's most sophisticated warplanes. The initials SR stand for Strategic Reconnaissance, in other words it is a spyplane. Details of its sensors remain classified and all SR missions are top secret. The plane is known to be equipped with radar, infra-red sensors and cameras capable of scanning more than 250,000 km^2 of the Earth's surface from a height of 24 km, in under an hour, and also able to focus on a golf ball from 24 km.

PERFORMANCE
Max speed 3,220 km/h at Mach 3
Servicing ceiling above 24,400 m
Endurance 1 hr 30 min at Mach 3
Range 4,023 km at Mach 3

DIMENSIONS
Length 31.65 m
Span 16.94 m
Height 5.64 m
Wing area 149.15 m^2

WEIGHTS
Empty 30,618 kg
Take-off 79,019 kg
Max fuel load 38,184 kg
Engines two at 14,742 kg each

RECORDS
London-New York 1 hr 55 min
London-Los Angeles 3 hr 41 min 39 sec
Distance 24,140 km in 10.5 hours
Sustained altitude 25,927.765 m



HEAVY-DUTY FLIER


Aviation Picture Library

The world's heaviest and most powerful bomber is the eight-jet, swept-wing Boeing B52 Stratofortress. It made the first ever non-stop flight round the world by a turbojet-powered aircraft in 1957. Twenty-three years later, the Stratofortress broke the record for the fastest non-stop round-the-world flight which took 42 hr 30 min. Refuelling was carried out in the air. The Boeing B52 Stratofortress can carry twelve thermo-nuclear short-range attack missiles (SRAM's) or twenty-four 340 kg bombs under its wings, and eight more SRAMs or eighty-four 226 kg bombs in the fuselage. It also carries four 12.7 mm guns in the tail turret.

- **Length** 48.02 m
- **Wing span** 56.38 m
- **Max speed** 957 km/h
- **Max take off weight** 221.35 tonnes
- **Max bomb load** 31,751 kg

overcome this problem by projecting computer-generated instrument readings into the pilot's forward field of view. The computer will be used to generate data, which is fed to miniature television screens mounted on the pilot's helmet. The same type of optics used in binoculars would then project the image into the pilot's field of view. Data would thus appear superimposed on the landscape before his eyes.

The system could also be used for night flying. An image intensifier night-sight could produce an image of the landscape and feed it to the pilot via his helmet projector system. The view could even be made three-dimensional by sending a slightly different image to each eye – just as in ordinary vision.

As well as 3-D vision, 3-D sound could be provided. For example, a radio message from another aircraft flying to the left of the plane would be arranged to sound louder in the pilot's left ear than in his right. This would make the sound appear to come from the direction of the aircraft that sent the message.

The pilot of the future may be able to control his aircraft by using his voice instead of his hands. Voice control would be a great time-saver as the pilot would no longer have to go through the process of looking for, and then pressing, a switch or button. He would be able to concentrate fully on the screen in front of him. Engineers in France have been working on such a system since 1982. Similar work is being undertaken in the UK and USA.

One of the main problems that has to be overcome is cockpit noise. The pilot's voice will be unable to control the aircraft if other sounds drown it out. Tests have shown that the computer can recognize as many as 96 per cent to 99 per cent of a pilot's commands, but even 99 per cent is not good enough. It is only when the system can recognize 99.99 per cent of the spoken commands that the equipment will be put into operation.

Visual control

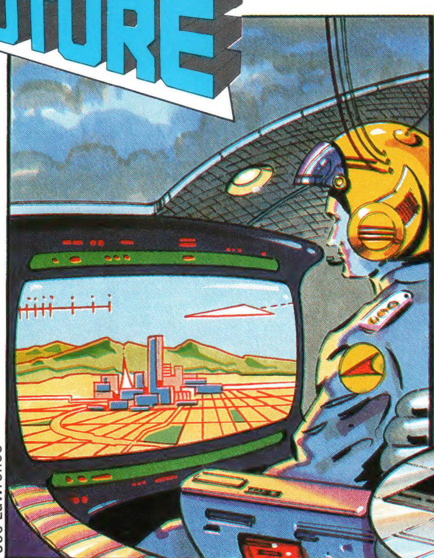
Aircraft designers are also looking at the possibility of switches that are activated just by looking at them, and systems that can read the pilot's brain waves.

The present-day pilot needs to see where he is going in order to fly safely. This is easy enough in daytime, but night flying is a different matter. Image intensifiers and night sights are already being used to enable pilots to see in the dark, but the pilot of the future may not need to see where he is going at all.

The satellite-based global positioning system, or GPS, will enable the pilot to know his position in three dimensions to within 16 metres. GPS will work out its position by means of signals from four or more orbiting Navstar satellites.

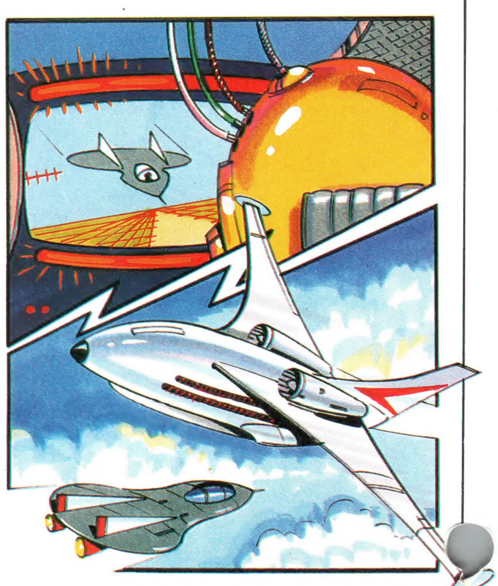
INTO THE FUTURE

WIRED FOR THOUGHT


Joe Lawrence

▲ *Tomorrow's planes will have a computer screen that simulates the terrain below. The image will be crystal clear – whether it is day or night.*

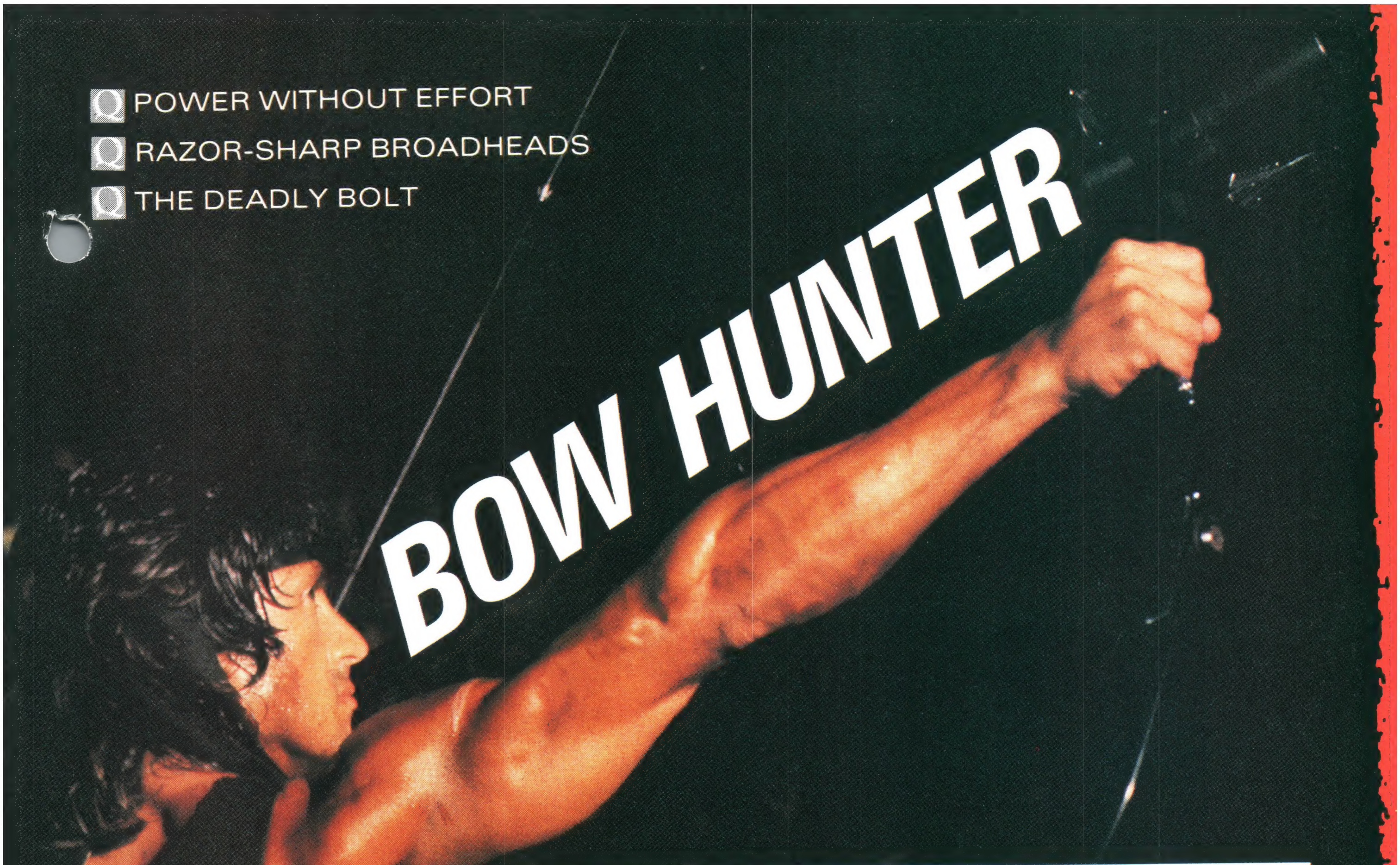
▲ *The pilot's head will be wired to computers, which can detect his brain waves. By thinking a command the pilot will control the plane.*



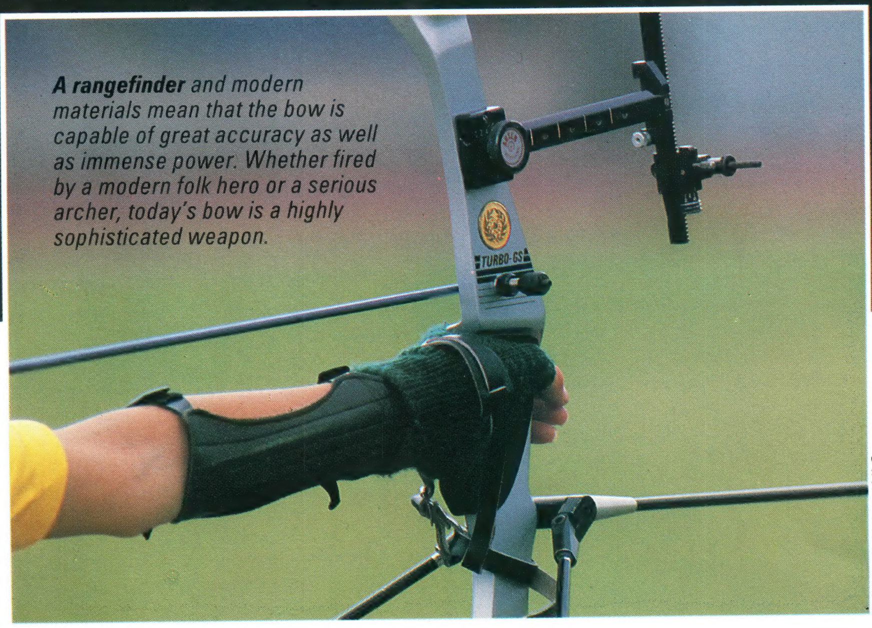
▲ *If the pilot gets tired or makes a wrong decision, the computers will modify his orders. This could involve taking evasive action to avoid a collision.*

POWER WITHOUT EFFORT
RAZOR-SHARP BROADHEADS
THE DEADLY BOLT

BOW HUNTER



Cannon/Kobal Collection



***A rangefinder** and modern materials mean that the bow is capable of great accuracy as well as immense power. Whether fired by a modern folk hero or a serious archer, today's bow is a highly sophisticated weapon.*

Pascal Rondeau/All Sport

TRAVELLING AT OVER 60 metres per second, a well-aimed arrow from a modern bow can bring sudden death to anything from a squirrel to a grizzly bear.

Armed with new versions of the traditional longbow and crossbow, or with the revolutionary compound bow, American hunters are leaving their rifles at home and going to the woods bow-hunting.

Today, the number of target archers in the USA is only a few thousand, but there are over two million bowhunters and more people are taking up the sport each year. One of the main reasons for the growing popularity of bowhunting is the compound bow, which first came on the market in the early 1960s. It is easier to use than a conventional longbow, and its high-tech look appeals to Americans.

Compound bows

The most obvious feature of a compound bow is the ingenious pulley-like systems of off-centre wheels and cables, which replaces the single string of an ordinary bow.

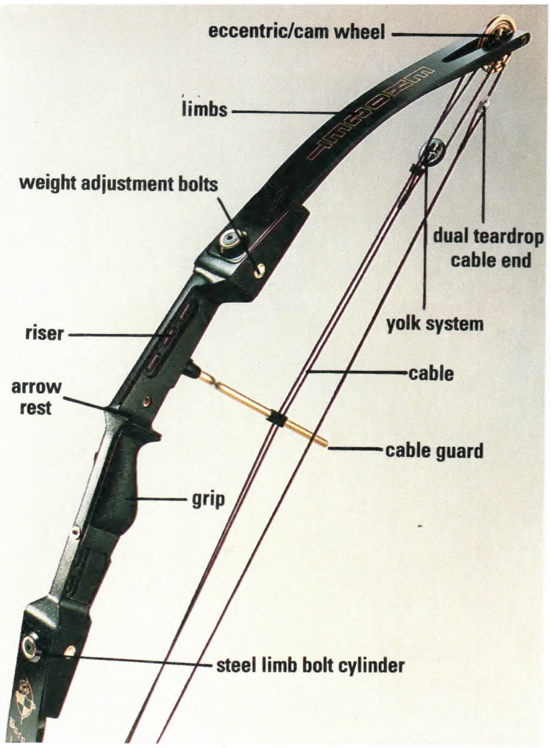
This cable system gives the arrow more rapid acceleration, and also makes it easier for the archer to hold the bow fully drawn while he takes aim. If an ordinary longbow needs a pull of, say, 20 kg to draw it, then it needs the same amount of force to hold it drawn. A compound bow of the same power still needs a pull of 20 kg to draw it, but only 10 kg – half the power – to hold it drawn. Since it can take a pull of 45 kg or more to draw a big-game bow, this is an obvious advantage.

The compound bow has a rigid wood or metal handle section in the middle, often shaped to give an almost pistol-like grip. On a hunting bow, this handle section may carry sighting and rangefinder scales and a rigid quiver to hold spare arrows.

The upper and lower limbs of a compound bow were originally made of wood or wood laminates, and although these are still used, limbs today are more likely to be made of plastic, magnesium, aluminium, glassfibre or carbonfibre. Each limb is fixed to the handle by a large bolt, and by tightening or loosening these bolts, the draw force of the bow can be varied.

The modern arrow

The arrows used for hunting are usually about 72 cm long, made of aluminium tubing or cedar wood. They have a razor-sharp triangular



Barnett International

A system of wheels *or cams, incorporated into the limbs of the compound bow, allows it to deliver power with the greatest possible economy of effort – the 'hold weight' of the bow is only half the 'draw weight'.*

Arrow technology *has advanced over the years to keep pace with bow technology. The modern arrow, unlike its predecessor, which was usually made of wood, is now made of aluminium with plastic flights instead of feathers. A well-aimed arrow could easily kill a fox, but hunting for game with a bow and arrow is illegal in the UK.*

broadhead at one end and flights of feather or plastic at the other.

The arrowhead is made as sharp as possible – and a good hunter will keep it that way – to ensure that it will kill the game and not just wound it, which would cause unnecessary suffering. A blunt arrow would also be a danger to the hunter, who could find himself confronted by a wounded and angry grizzly bear or mountain lion, with no time to reload and shoot again.

Despite arrow speeds of up to 60 metres per second, hunting with a compound bow can be far more difficult than with a rifle, because of the bow's shorter range. If he is going to have any chance of a kill, the bowhunter has to be able to get to within about 35 metres of his quarry without being detected. But if a bowhunter wants longer range, he can switch to a more powerful weapon – the crossbow.


Pascal Rondeau/All Sport

In the UK, crossbow ownership is regulated. No-one under the age of 17 years is allowed to purchase one of these bows, although individuals under 17 years can use them provided they are supervised by an adult of 21 years or over.

Crossbows

Shooting with a modern crossbow is more like using a rifle than a bow. The limbs of the bow, called 'prods' on a crossbow, are mounted at the end of a 'barrel', similar to a rifle stock, with a trigger mechanism. Many hunters fit their bows with telescopic sights.

The barrel is usually made of wood or light alloy, and the prods of laminated wood, glassfibre or carbonfibre. To cock the bow, the string is pulled back by hand, or by a lever or winch mechanism, and hooked on to the top of the trigger mechanism.

For hunting, the bolt (as the crossbow arrow is called) is between 35 and 45 cm long – much shorter than a hunting arrow, but carrying the same lethal broadhead and flights of feather or plastic. The effective hunting range is up to 55 metres, and bolt velocities can be over 75 metres per second.

Like the compound bow, the crossbow is used for hunting anything from small game such as rabbits to deer and big game, including elk and bear. There is no recoil, so the crossbow is more comfortable to shoot than a large-bore rifle. But contrary to popular belief it is not all that silent.

For small game at close range – up to 15 metres – there are a number of crossbow pistols on the market. They shoot miniature bolts, and some even have a rotating barrel system holding five bolts. After each shot, the bow is recocked and the barrel turned to bring the next bolt into position.

Just amazing!

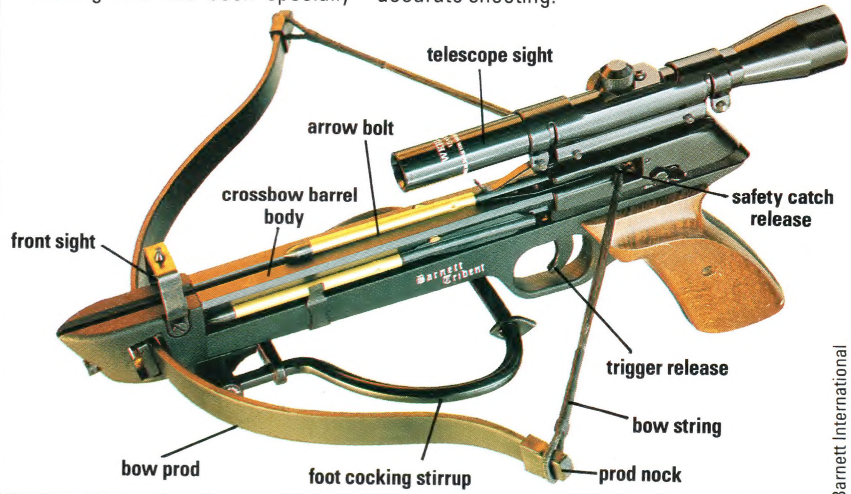
CANNED KILLER

TO LURE SCAVENGERS SUCH AS COYOTES WITHIN RANGE OF THEIR BOWS, AMERICAN HUNTERS CAN NOW BUY CANS OF DISTILLED ROTTEN MEAT CALLED 'DEAD HORSE'.


Paul Raymonde

A LETHAL WEAPON

The crossbow pistol has a three-shot magazine for simplified loading and has been specially designed to withstand reverse recoil, which allows for more accurate shooting.



Barnett International

DECOYS

ARMOUR PIERCERS

EVADING RADAR

COUNTER ATTACK

Rockwell International

The Rockwell B-1B *bomber is hard to detect as it provides a poor target for radar.*

A TV-guided AGM-65 *Maverick air-to-surface missile is launched from a US Air Force F-16B fighter.*

Hughes Aircraft Company

SOME OF THE LATEST aircraft can not only escape from the missiles fired at them, they are designed in such a way that they are less visible to radar, so are unlikely even to be spotted by the enemy.

Whenever a new or improved weapon enters service, it is usually only a matter of time before someone comes up with a defence against it. When anti-tank missiles were first introduced, they could almost be guaranteed to make a kill, but soon new armour was developed to resist them.

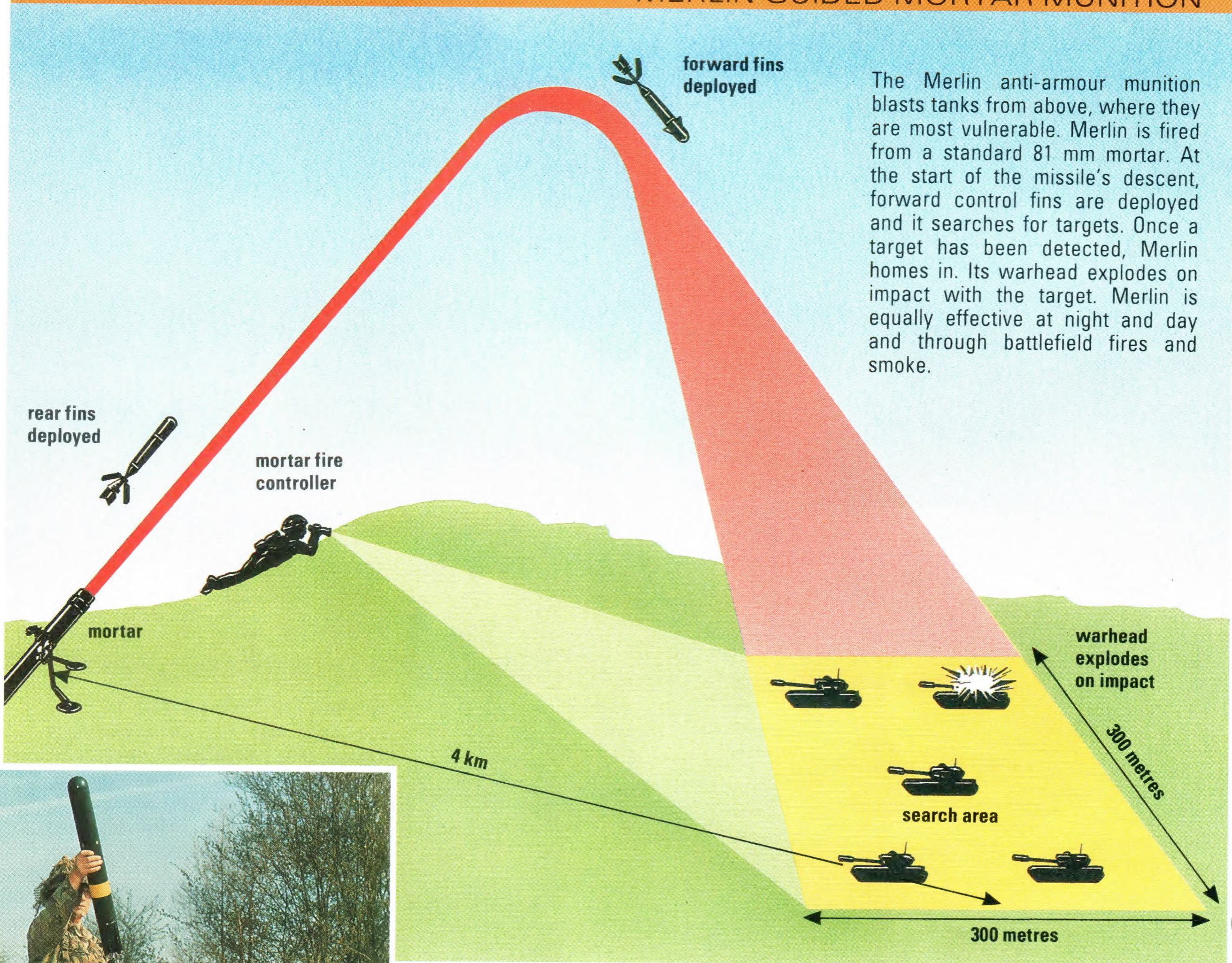
Among the toughest tanks in the world, equipped with special armour, is the Russian T-72 main battle tank (MBT). This tank, together with its specialist versions the T-74 and T-80, is in service with several ex-Communist armies. It is designed to spearhead a major conventional attack. The armour is specially made to withstand almost any shell or missile.

Tank armaments

The main armament of the T-72 is a 125 mm smooth-bore gun, with an automatic loading system, which gives it a rate of fire of eight shots a minute. To make these shots lethally accurate, the T-72 has a laser rangefinder and a computer-controlled gun stabilizer. Once the gun has been aimed, sensors monitor the motion of the tank, and the stabilizer continually alters the angle of the gun, keeping it trained on the target as the tank moves.

For use against tanks and other armoured vehicles, the T-72 carries two main types of armour-piercing shell. The first is called an armour-piercing, discarding sabot (APDS)

MERLIN GUIDED MORTAR MUNITION



The Merlin anti-armour munition blasts tanks from above, where they are most vulnerable. Merlin is fired from a standard 81 mm mortar. At the start of the missile's descent, forward control fins are deployed and it searches for targets. Once a target has been detected, Merlin homes in. Its warhead explodes on impact with the target. Merlin is equally effective at night and day and through battlefield fires and smoke.

shell. It has a small diameter, solid tungsten carbide shell enclosed in a 125 mm light alloy sleeve, or sabot.

When the shell leaves the barrel at a speed of 1,615 metres per second, the light-alloy sabot breaks up and falls away, and the shell flies on to smash through the armour of its target. It can penetrate ordinary cast steel armour up to 300 mm thick at a range of 1,000 metres, and its maximum range is 2,100 metres.

The second type of shell is a high-explosive anti-tank (HEAT) round, which leaves the gun at 900 metres per second. When the shell hits its target, a detonator ignites its explosive warhead. The nose of the shell is designed to focus the blast of the explosion into a narrow jet. This punches through the armour, erupting into the tank as a stream of hot gases and molten metal.

Both types of armour-piercing shell used by the T-72 are stabilized by fins to make them more accurate. So is the high-explosive fragmentation shell it carries for attacking troops or buildings. Its maximum range is 9,400 metres.

As well as the massive 125 mm main gun, the T-72 carries two machine guns: a 7.62 mm gun at the front of the turret, and a 12.7 mm gun on top. Both can be used against ground targets, but the T-72 can also use its 12.7 mm gun to defend itself against attack from the air – one of the biggest threats to a modern tank.

Air attack

The turret of a tank is its most vulnerable point. It has to be relatively light to be swivelled quickly, so the armour cannot be as heavy as that of the tank's hull. And because it has various hatches, gun ports, and gunsight and periscope

Ilkka Ranta/Lehtikuva/Colorific!

***The T-72 tank**, seen here at a Soviet parade, is now used by most ex-Soviet states.*

McDonnell Douglas Corporation

***The AH-64A Apache** attack helicopter is heavily armed and carries Sidewinder and Stinger air-to-air missiles as well as eight Hellfire anti-tank missiles on its wing pylons.*

mountings in it, parts of it cannot be fully armoured at all.

An attack from the air is one of the surest ways to destroy a tank, blasting its turret apart with a missile, a bomb or a hail of armour-piercing bullets. A ground-attack fighter firing Maverick missiles, or a McDonnell Douglas AH-64 helicopter with its Hellfire missiles, can take out any modern MBT, including the T-72.

Whenever a jet or helicopter gets close enough to enemy tanks to attack them, it might also find itself within range of the enemy's anti-aircraft guns and missiles. Anti-aircraft missiles are guided to their targets by radar beams, heat-seeking sensors, television cameras or laser beams, so modern strike aircraft need ways of confusing or jamming the missile guidance systems to avoid disaster.

Obscured by clouds

The simplest forms of defence against anti-aircraft missiles – whether surface-to-air or air-to-air – are decoys dropped from the aircraft to lure the missiles away from it.

Radar-guided missiles can be put off the scent by 'chaff' — a cloud of short, metal-coated plastic fibres, each about 0.1 mm in diameter. When the aircraft's radar warning receiver detects a missile guidance radar locked on to it, the plane releases chaff.

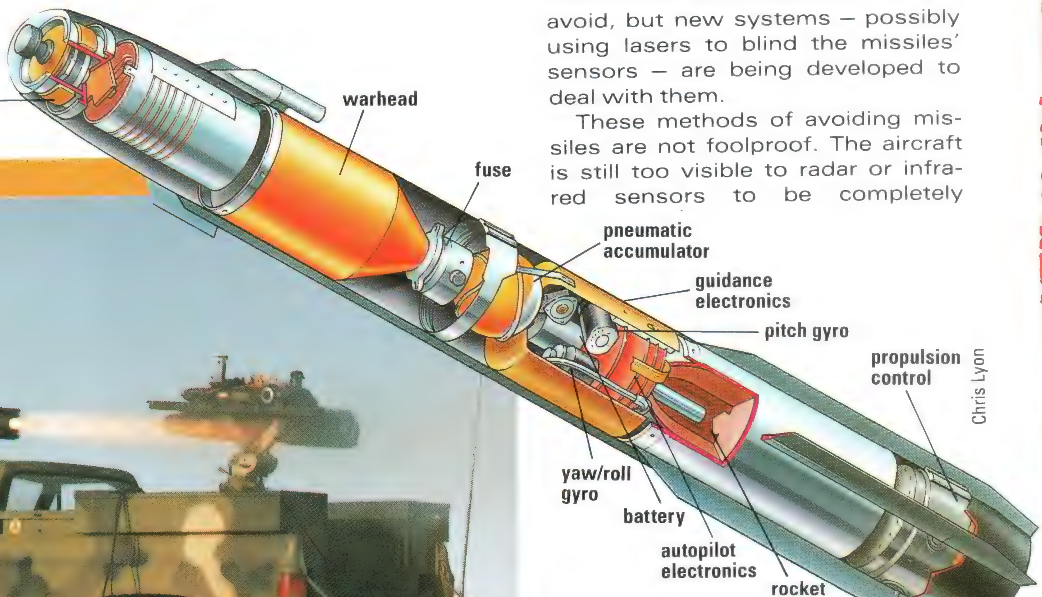
The chaff forms a slowly-drifting cloud, and the metallic coating of the fibres reflects the radar signals, just as the aircraft does. The missile homes in on the larger chaff cloud, while the plane flies on unharmed.

Heat-seeking missiles home in on the infra-red (heat) radiation given off by the aircraft's hot engine exhausts. To fool these missiles, the plane fires fiercely-burning flares. The missile follows these instead of the aircraft.

A more complicated, but highly effective, defence against missiles is to use electronic systems, called electronic countermeasures (ECM), to create false radar or infra-red signals that send the missiles off course. Missiles guided by television or lasers are more difficult to avoid, but new systems – possibly using lasers to blind the missiles' sensors – are being developed to deal with them.

These methods of avoiding missiles are not foolproof. The aircraft is still too visible to radar or infra-red sensors to be completely

HELLFIRE



Chris Lyon

Rockwell International

Hellfire missiles are effective against tanks, bunkers, ships and helicopters. These missiles can be launched from land, sea or air. The solid fuel rocket motor enables Hellfire to move faster than sound.

TRH/IAI

Israeli Kfir C2 fighters, *armed with Shafrir air-to-air missiles, stand ready on the runway.*

immune from a successful attack.

Because of this, the Americans (and perhaps the Russians too) are spending a lot of time and money on developing planes that are invisible to radar and other detection systems – the so-called 'Stealth' aircraft.

Stealth technology

Radar signals are reflected by metal surfaces, especially if they are flat or sharply angled. To reduce the amount of radar signals they reflect, Some Stealth planes have smooth curved surfaces that let the radar beams bend around them, and as many parts of them as possible are built of non-metallic materials, such as carbon fibre.

Those parts of the plane that must be made of metal, such as the engines and the weapons, are concealed within it and surrounded by surface materials that absorb radar waves.

Besides confusing radar systems, Stealth planes can avoid being detected from the ground by using their infra-red emissions. The engine outlets are on top – instead of below or at the rear of the plane – and the exhaust gases are cooled by mixing them with cold air as they leave the engine.

Despite all this, there is still a chance of the plane being detected by very sensitive radar, or from its own radar signals. So Stealth planes are equipped with highly complex ECM systems. These mislead enemy radars about the size, speed, position and direction of the planes, making it difficult for the enemy to know whether, or how, to attack them.

STINGER MISSILE

The Stinger anti-aircraft missile is fired from the shoulder and uses a heat-seeking guidance system to home in on the target. Each weapon costs about $50,000 and weighs nearly 16 kg. After an eight-week training course, troops using the Stinger missile score a 70 to 80 per cent hit rate.

Gamma/Frank Spooner Pictures

Secrets revealed

Some aspects of Stealth technology are used on the Rockwell B-1B bomber. Its smooth shape, especially when seen from the front, and the design of its engine air intakes give it a radar 'signature' — the size it appears to be when seen on radar — of between one-tenth and one-hundredth of that of its predecessor, the B-52.

Two much more advanced Stealth planes were originally so secret that the US Government denied their existence. These are the F-117A Stealth jet fighter and the Stealth B-2 bomber. The F-117A has sharp points and edges that give a highly confusing image on enemy radar screens. This design contrasts with the rounded edges of the B-2, which are designed to minimize radar reflections.

Just amazing!

HIGH-SPEED MISSILE

THE RUSSIAN SA-10 'GROWLER' AIR-TO-SURFACE MISSILE TRAVELS AT ABOUT 120 KM PER MINUTE. THAT'S LONDON TO SYDNEY IN ONLY 2 HOURS 20 MINUTES!

Paul Raymonde

US Air Force

The B-2 Stealth bomber *was designed by Northrop Corporation in conjunction with Boeing and Vought. It is powered by four concealed F101 engines.*

THE NUCLEAR AGE

- FISSION AND FUSION
- THE NEUTRON BOMB
- DEADLY WARHEADS

NUCLEAR WEAPONS ARE THE most destructive ever invented. The massive explosive power of just one intercontinental missile, with multiple warheads, could destroy a whole city.

The power of a nuclear weapon is measured in terms of the amount of TNT (trinitrotoluene) it would take to make the same size of explosion. A typical 203 mm nuclear artillery shell has a power, or 'yield', of 1 kiloton, the same as about 1,000 tonnes of TNT. But the power of the larger weapons is measured in megatons – a 1-megaton blast has the same power as the explosion of a million tonnes of TNT.

The blast from an explosion goes up into the air as well as downward and along the ground, so, doubling the yield of a warhead will not double the amount of actual ground damage it can do. A 1-megaton explosion will destroy a city area of about 50 sq km, but a 2-megaton explosion will only destroy about 80 sq km, not a hundred as you might expect.

The yield of a large nuclear weapon is often given in 'equivalent megatons'. This is the number of 1-megaton warheads required to cause the same amount of damage as that particular weapon. A warhead with a 2-megaton yield has an equivalent megatonnage of 1.6, because it will cause the same damage as 1.6 1-megaton warheads.

A single 1-megaton warhead, exploded over the Houses of Parliament in London, would totally destroy an area stretching from Brixton in the south to King's Cross in the north, and from Knightsbridge in the west to Bermondsey in the east, a total area of nearly 30 sq km.

Minuteman III takes off *on test. 1,000 Minutemen stand ready in underground silos (inset) in the USA. They have three independently targetable warheads.*

Department of Defense/USAF Boeing Aerospace Inset

Since the world's nuclear powers have a total of over 20,000 megatons in their arsenals, they have the ability to inflict an unbelievable amount of damage on each other.

Nuclear explosions

All nuclear weapons can be divided into two main types – fission weapons and fusion weapons.

Fission weapons were the first to be developed. These contain heavy elements, such as uranium 235 and plutonium 239, that contain a great many atomic particles. When the weapon explodes – triggered by a charge of high explosive slamming two pieces of uranium plutonium

Just amazing!

HI-ENERGY BAR

ON 30 OCTOBER 1961, THE USSR DETONATED THE WORLD'S LARGEST NUCLEAR EXPLOSION OF 57 MEGATONS. THE ENERGY RELEASED WOULD HAVE KEPT A ONE BAR ELECTRIC FIRE GOING FOR NINE YEARS.

Paul Raymonde

together – the heavy atoms split into the smaller atoms of lighter elements and energy from within the original atom is released in a massive blast of heat, light and other forms of radiation.

Fusion weapons, also called hydrogen weapons, work in a different way. Instead of splitting heavy atoms into lighter ones, they join, or fuse, hydrogen atoms together to form larger ones. This releases a vast amount of energy.

A temperature of several hundred million degrees is needed to create a fusion reaction. In a hydrogen bomb, this temperature is created by a small fission bomb 'trigger'. The trigger is surrounded by a layer of a metallic substance called lithium deuteride – a compound that contains the hydrogen atoms which will fuse together when the bomb goes off. Because of the high temperatures needed to make them work, fusion bombs are also known as thermonuclear weapons.

Tactical weapons

Theatre nuclear weapons are intended for use during a battle, especially one within the so-called European theatre of operations, at ranges of up to 5,500 km.

Those with a range of less than 200 km are classed as tactical or battlefield weapons. They include nuclear artillery shells and short range missiles, which can be used to attack enemy tank formations and airfields, and nuclear depth bombs for attacking submarines.

Nuclear artillery shells have yields of 1 to 2 kilotons, and are fired from self-propelled howitzers or towed guns. They have a range of 30 km.

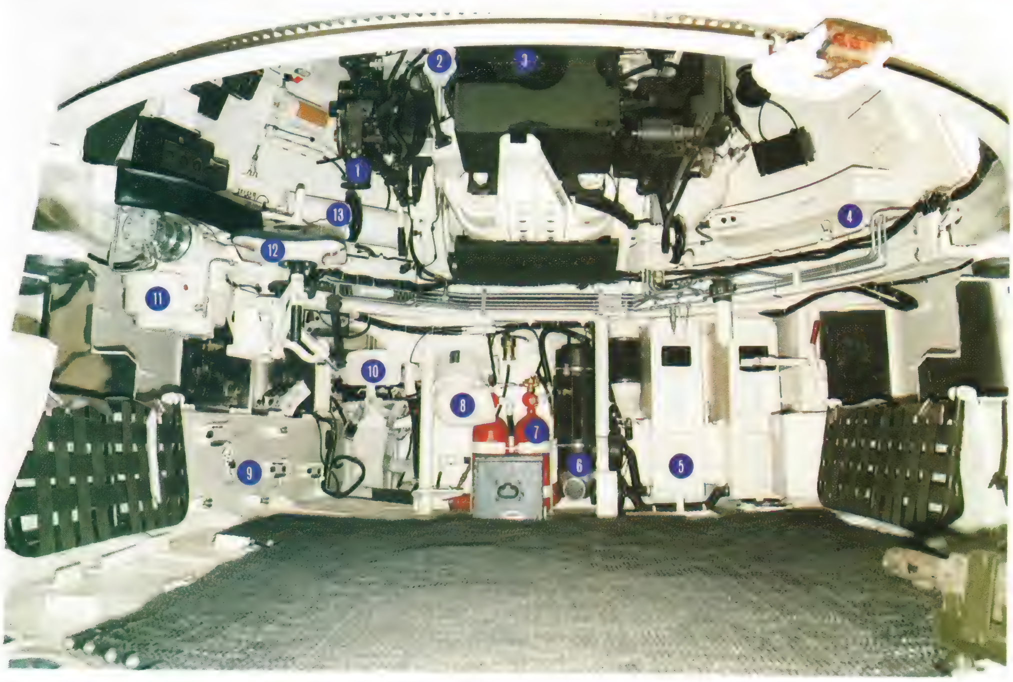
Short-range missiles include NATO's 50-kiloton Lance, with a range of 110 km, and the Soviet Union's SS-21. These missiles can be fitted with either conventional high-explosive or nuclear warheads.

Intermediate weapons are used at ranges of up to 1,000 km, and long-range intercontinental ballistic missiles (ICBM) to 6,500 km. These categories overlap because they include bombs and shorter-range air-launched missiles delivered by strike aircraft and bombers.

A series of arms control agreements signed by the US and Russia in 1991 and 1992 have reduced the number of tactical and strategic nuclear warheads owned by both nuclear superpowers from over 20,000 each to about 4,700 each. Certain categories, in particular land-based multiple warhead ballistic missiles and ground based cruise missiles, have been abolished altogether.

***The M110 gun** fires nuclear and conventional shells. It can fire a nuclear device up to a range of 21 km.*

US Dept. of Defense, Portsill, Oklahoma



***Inside the launch vehicle** that bears the M110 gun. Major features include:*

1 Dial sight mount
2 Elevating cylinder
3 Breech mechanism
4 Rifle rack
5 Engine air cleaner
6 Personnel heater
7 Fire extinguisher
8 Air ventilating fan
9 Three rifle racks
10 Driver's seat
11 Traversing mechanism
12 Left gunner's control

TRH/USAR

Inside a mountain *in the USA, the North American Air Defense Command (NORAD) keeps watch against enemy nuclear attack.*

The Neutron bomb, or enhanced radiation weapon (ERW), was suggested as a battlefield weapon for attacking tanks and armoured personnel carriers.

The neutron bomb creates a smaller area of blast damage than a standard battlefield fission bomb, but it produces more 'prompt' radiation in the form of gamma rays and neutrons. The prompt radiation, which is lethal in high doses, would

TRH/DOD

kill the crews of the enemy tanks over a wider area but cause less destruction than a standard bomb.

However, many experts doubt that it would really be more effective against armoured vehicles than a standard 203 mm nuclear artillery shell or a tactical nuclear missile.

Long range attack

Strategic weapons are designed to be used directly against an enemy's homeland, rather than against his troops on the battlefield. In a nuclear war, this means attacking missile silos, command centres, radar and satellite ground stations, air bases, ports, and even the cities.

Strategic nuclear weapons include both bombs and missiles. The bombs are delivered by long-range bombers such as America's Rockwell B-1B, which has an unrefuelled range of up to 12,000 km. It can carry either free-fall bombs or air-to-surface missiles, or both.

The Russian equivalent of the B-1B is the Tupolev Tu-22M bomber, code-named 'Backfire' by NATO. This plane is similar in many ways to the B-1B, but it is much larger and faster. Its unrefuelled range is 17,300 km, and like the B-1B it can carry free-fall bombs or air-to-surface missiles.

Ballistic missiles

Bombers are key parts of the strategic forces of both superpowers, but the most important weapons are the intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs), most of which have multiple warheads.

Launched from underground silos, mobile land-based launchers or from submarines, ballistic missiles climb high above the atmosphere before they release their deadly warheads.

Separated from their missile 'buses', the warheads re-enter the atmosphere and fall on a precisely-calculated path to their targets.

Early ballistic missiles had single warheads, and some still do. When defensive missiles, able to destroy incoming warheads, were developed, the idea of putting several separate warheads on each ballistic missile was born.

Raining warheads

These warheads, carried in multiple re-entry vehicles (MRVs), could be released from the missile bus in a controlled sequence. There would be more chance of one or more of them evading the anti-missile defences, and the damage would be spread out over a wider target area than with a single warhead.

A more complex version of the MRV is the MIRV – the multiple independently-targetable re-entry vehicle. The MIRVs are ejected from the missile bus at different times and in different directions, and at different speeds, so that they travel to several different targets. Most American and Russian strategic missiles have MIRVs.

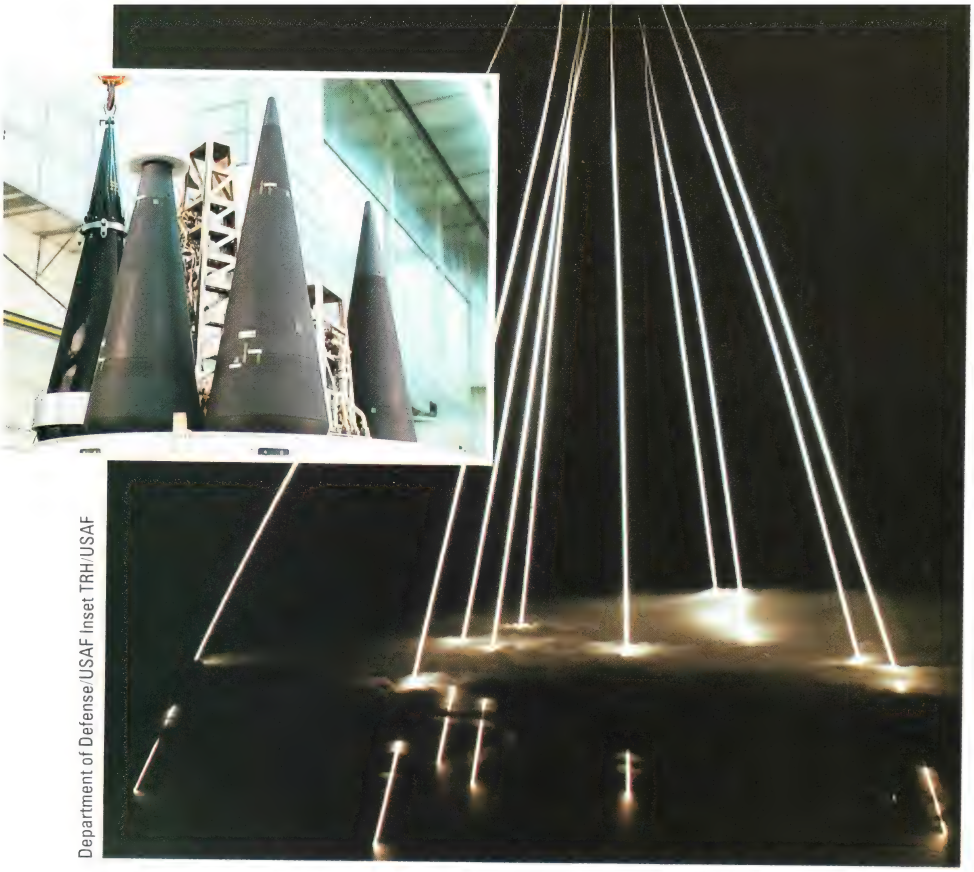
Strategic missile warheads can be adjusted to explode at different heights over their targets. A warhead targeted on a city would be detonated before it hit the ground, to spread the damage further.

However, to attack a hardened target such as a missile silo or an underground control room, it would detonate close to the ground or on

Emil Schulthess/Black Star/Colorific!

The military might *of the USSR was paraded yearly on May Day in Red Square. But the new Russian state has dispensed with such militarism.*

The SS 21 *missiles form a major part of the Russian nuclear armoury. They have a range of 120 km.*



Department of Defense/USAF Inset TRH/USAF

The ten re-entry vehicles of a Peacekeeper missile pierce their way through clouds, bearing their lethal warheads (inset).

impact. To make them more effective against underground targets, some future warheads could plunge deep into the ground before they explode.

The Peacekeeper

America's latest missile development is the MGM-118A Peacekeeper, formerly known as the MX. This missile, 21.6 metres long and weighing 87.5 tonnes, carries ten Mk 2 MIRVs, each armed with a 300-kiloton W87 warhead. It has a maximum range of 14,000 km.

The first ten Peacekeepers are deployed in silos previously used to house Minuteman III missiles, but the rest are to be mounted on special railway trucks.

The advantage of using mobile launchers, such as trains, is that unlike fixed silos whose positions are known accurately, it is very difficult for an enemy to successfully launch a missile attack on a continuously moving target.

The same type of rail launcher is being used for the Russian SS-24, which is similar in size to the Peacekeeper, but much heavier at around 100 tonnes. Its range is 10,000 km, and it is armed with ten 350-kiloton MIRVs.

ON THE SCRAPHEAP

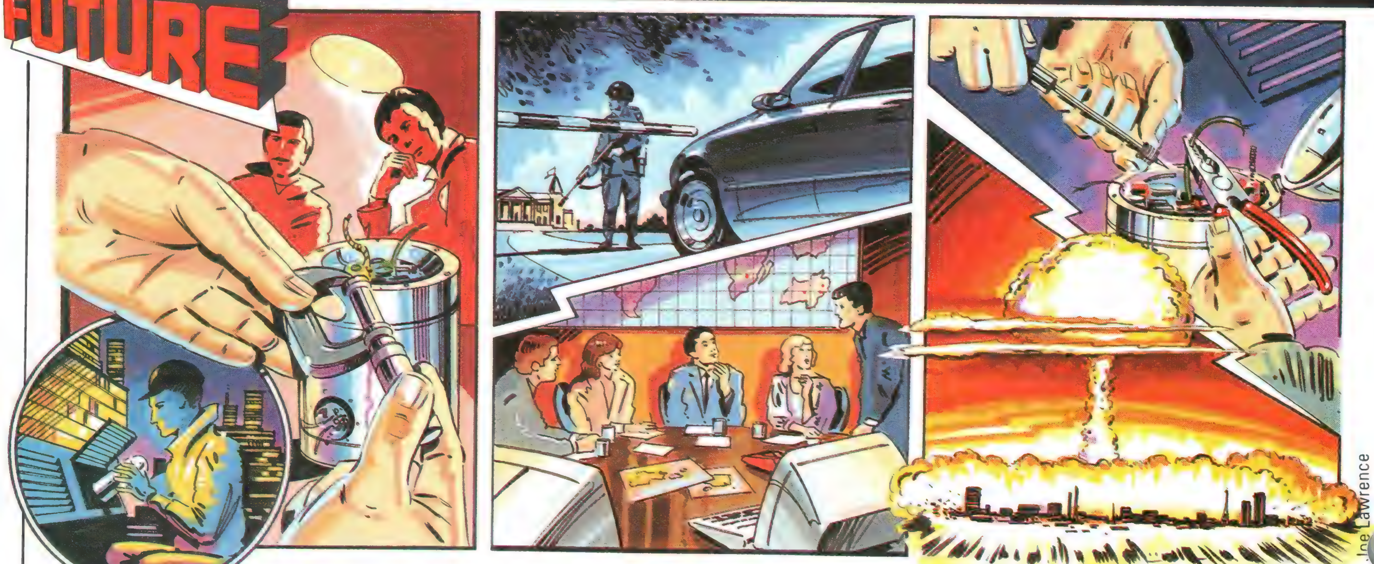
The futility of adding to their already bursting nuclear arsenals has at last been acknowledged by the Superpowers. In the USA at Davis-Monthan Air Force base, contractors try to arrive at the quickest and cheapest way of dismantling ground-launched cruise missiles.

Special saws are used to cut through the missile storage canisters and a plasma-arc welder is used to cut through the larger parts of the missile's bulkhead. The missile is then split apart for disposal. After cutting is complete, each piece must be further cut in half before it is finally scrapped.

Gamma/Frank Spooner Pictures

INTO THE FUTURE

URBAN A-BOMBS



Joe Lawrence

▲ Terrorists would be able to make a small nuclear bomb from black market plutonium and hide it to use for bargaining.

▲ Negotiations would be extremely delicate and would have to be kept top secret. The slightest news leak would cause untold chaos and panic.

▲ Should the negotiations be successful, the bomb could be defused. But if negotiations broke down or failed, the consequences would be incalculable.

INTENSIVE FARMING

AUTOMATION
LIVESTOCK
POISON BAITS


ZEFA

***Young chickens** live in a broiler house (below) when reared for their meat. Laying hens are kept in wire cages (left). Their eggs roll to the front of the cage and their droppings fall through the floor.*


Waller/Jerrican

SCIENCE AND TECHNOLOGY are playing an increasing role in farming as it becomes more and more intensive. In livestock farming, intensification improves productivity of meat, eggs, and milk by increasing the numbers of animals supported by available land. It also reduces the amount of labour required for management and increases the productivity of the individual animal.

When the numbers of animals on the land are increased, it creates problems. Livestock can no longer support themselves by grazing or foraging, and must have expensive supplements or manufactured feeds. Disease is often a problem, and diets and housing techniques are often adapted to minimize this. Disease is also a major threat to arable farming. So fields are often sprayed with chemicals to prevent disease and also to control pests that eat the crops.

Pest control

Pests include animals that attack crops and also those that attack farm animals and man, often transmitting disease organisms to them. About a quarter of the world's food supply is consumed or destroyed by pests, mainly insects, worms, rats and mice. Much sickness and disease is spread by pests such as mites, ticks, mosquitos, tsetse flies and snails. Other prevalent pests include birds, millipedes, woodlice and slugs.

Indirect ways to control pest attack include crop rotation and choice of crop variety to avoid attack. Crop rotation is most effective against relatively immobile pests, insects that over-winter in the soil, and pests that attack only one particular crop.

Direct control

Poison baits, seed treatments, and sprays, dusts, or granules containing potent pesticides are various means of direct control. For pests in soil, warehouses and buildings, fumigants are normally used. These are usually liquids but sometimes

Grain storage containers *range from small bins to huge concrete buildings with built-in equipment for filling, emptying, weighing, drying and blending the grain. The storage shown here has a tilting platform for emptying truckloads of grain rapidly.*

powders, which vaporize and spread themselves throughout the infested area. In glasshouses, smoke canisters and aerosols may be used.

Spraying, dusting and granule applying machinery cannot pass through tall or mature crops, so these must be treated from the air. Fixed-wing aircraft are cheapest for large areas, but helicopters have several advantages. They are more manoeuvrable, do not require landing strips, and the downdraught they generate helps to force pesticides into crops.

Because rats and mice are wary, unpoisoned bait is first offered. When the rodents are feeding freely, poison bait is substituted.

The numbers of most pests are limited by naturally occurring enemies. For example, ladybird beetles feed on greenflies, ichneumon flies lay eggs in the young of many insects. And predatory beetles and spiders kill various pests. Unfortunately, some pesticides kill many of these beneficial species, resulting in an increase of other pests. The red spider mites have increased greatly since orchards were sprayed to control various pests and diseases, mainly because spraying kills their principal enemy, the red-kneed capsid.

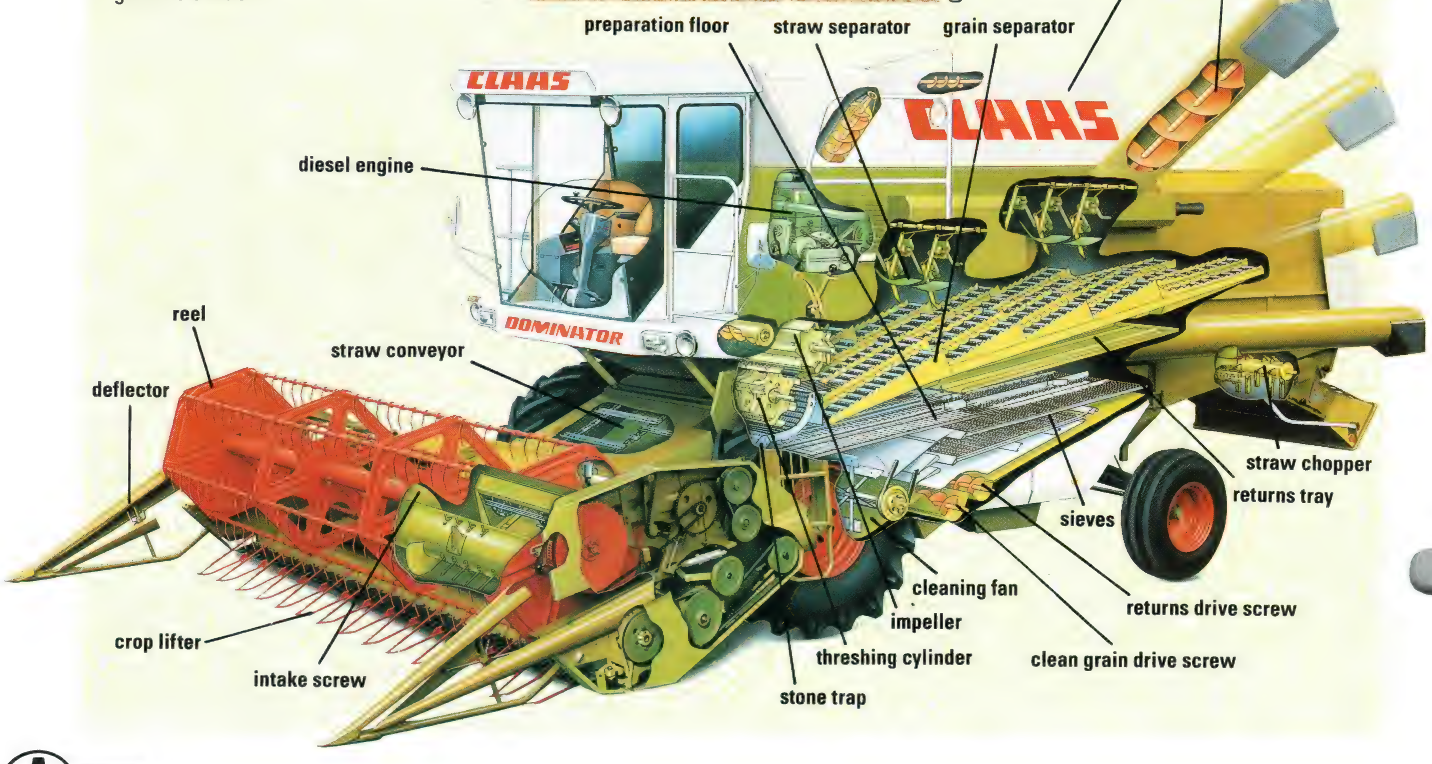
To avoid these problems, scientists are trying to decrease or eli-

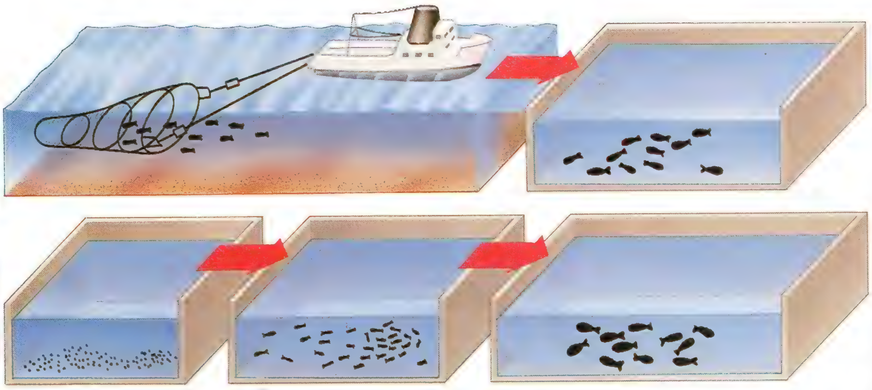
BIOLOGICAL CONTROL

A species of wasp is put on some crops to prevent them from being eaten by caterpillars. The tiny female chalcid wasp pierces the eggs of the cabbage moth and lays her own eggs inside. The moth eggs never develop into caterpillars because they are eaten by grubs that emerge from the wasp eggs. This technique, a form of biological pest control, is widely used in China.

THE COMBINE HARVESTER – A MULTI-PURPOSE MACHINE

The combine harvester is used first to reap the grain crop and then thresh it to knock the grain from the straw. Grain separators remove the straw from the grain and deposit the straw back on to the ground. The grain is transferred by means of an auger (a drive screw) to a tank at the top of the machine. An unloading auger later transfers this grain to a truck.





Mark Franklin

***Fish farming** takes many forms. The young fish may be caught at sea (top) and transferred to tanks on land. There they can be fattened until ready for market. Another method (above) is to hatch and mature the fish in a series of tanks.*

SALMON FARMING

Salmon is a luxurious fish, prized for its delicious flavour. The great demand for this fish has led to the development of salmon hatcheries. Salmon are more difficult to farm than other fish as they live partly in the sea and partly in fresh-water streams and rivers. Some months after hatching in fresh water, the young fish swim to the sea, where they grow into adults. In a hatchery, the female salmon lays her eggs in fresh water. The fry (young fish) are first confined to a stretch of river. They are later transferred to the sea, where they are kept and fed in netting enclosures or cages. It takes about three years to produce a 9 kg salmon from the egg.

minate pesticides and encourage the natural enemies of the pests. In biological control, natural enemies such as predators, parasites, fungi, bacteria, or viruses are used to control pest species. These techniques have met with some spectacular successes.

One of the newest forms of biological control is the use of insect hormones. If the right insect hormone is synthesized, it can be used to interrupt that insect's life cycle at a critical stage and thus lead to its extermination. Because the hormone affects a system peculiar to one type of insect, other creatures are unaffected.

Fish farming

In nature, only a fraction of one per cent of the eggs that are spawned by most species ever survive to become fish of marketable size. Fish farms, however, produce a much higher yield.

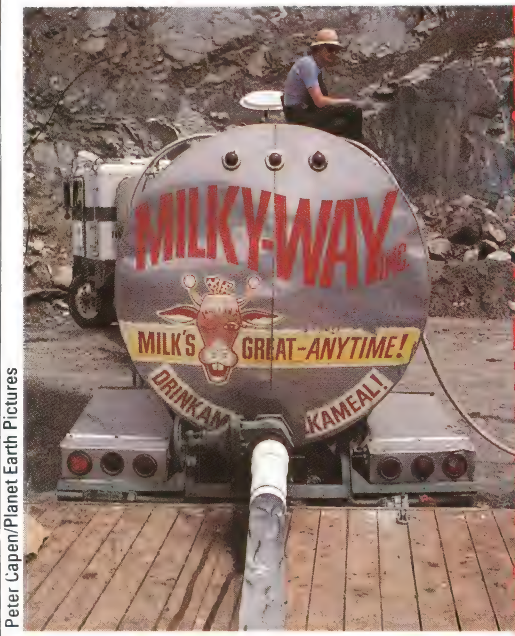
Fish farming, or aquaculture, takes many forms. Some trout farms are elaborate complexes of concrete raceways, pumps, aerators and equipment to remove waste products and excess nitrogen from the water, and restore oxygen and acidity so that the water may be recirculated. Some species can live in virtually stagnant water with much plant growth, because they require comparatively little oxygen and their diet consists of vegetable matter and small aquatic life.

Cold-water species, such as trout, require clear, well-oxygenated water, and the commercial rearing of carnivorous species like trout, salmon, eels, turbot and sole depends upon supplies of feeding stuffs containing a high proportion of animal protein. One source of feeding stuffs is fish of species difficult to sell for direct human consumption.

Maximum meat

In all intensive systems, animals producing eggs or milk or being fattened for meat production, are separated from the breeding stock. Maximum meat productivity is achieved by selective breeding to produce as many offspring as possible. Breeding has also changed the appearance of farm animals. For example, today's pig is a streamlined meat machine far different from its hardy, bristly ancestor. It is the end result of breeding that has drastically changed the animal's shape to suit the public demand for lean meat. The pig has been adapted so well to its new role that half the meat eaten in the world comes from pigs.

Growth rates slow as animals near maturity, so livestock is usually slaughtered while still relatively young. By doing this, the food consumed by the animals is converted to the maximum possible weight of flesh. To raise them until they are fully grown would require a disproportionate quantity of feed. For example, a broiler chicken reaches a weight of 2 kg in seven



Peter Capen/Planet Earth Pictures

***Small live fish** are transported by road to and from fish farms in tankers. The water and fish are simply pumped up into the vehicle through a large-diameter pipe.*

***Modern pig-breeding** units have narrow stalls in which the pregnant sows are often confined for most of the time. There they produce litters of about ten piglets. Most sows have two litters every year.*

ZEFA

***A modern milking parlour** has electronic equipment to recognize each cow's identification tag. A message on a computer screen then informs the herdsman of any special checks or treatment required. For example, the milk may have to be tested for drugs if the cow has had medical treatment.*

Berenguler/Jerrican

***Mustering cattle** by helicopter saves valuable time on the vast ranches of Australia.*

Richard Woldendorp/Susan Griggs

weeks, when it is normally killed. For each 1 kg of feed it consumes, it gains 0.45 kg in weight. But if it is allowed to grow to a large size, it will soon take 1.4 kg or more of feed to put on the same amount of extra weight.

Food and drugs

In animals growing at such a rapid rate, nutritional requirements continually change, and very careful control of feed ingredients is necessary. Growth rates may be further stimulated by supplementing the diet with growth-promoting substances, such as antibiotics.

With so many animals in an intensive farming unit, part or all of the feeding process is automated. A modern pig-feeding system, for example, includes a large mix tank, a feed pump and electronic weighing units. Many different feed ingredients, solids and liquids can be mixed and delivered in programmed quantities to exact requirements with no wastage. Timers release the mixed feed two or three times a day through pneumatically operated feed valves into troughs in the separate pens. Each pig or group of pigs receives exactly the amount previously calculated and keyed into the control box, and it can take as little as seven minutes to feed 400 animals.

Free range farming

In recent years many people have begun to question some of these modern livestock farming methods. It is claimed that some types of factory farming are cruel and cause unnecessary suffering to the animals.

Several farmers have begun keeping their animals in 'free range' conditions. This means that the animals have plenty of space to move about, usually in the open air. They find much of their food themselves, the diet being supplemented only with specialist foods or during the winter.

Meat, eggs and dairy products produced by these methods are labelled as free range. They usually cost more than factory farmed products, but often taste better. The customers who choose to purchase free range products may do so because they wish to be certain that no animals have suffered needlessly, though some factory farm techniques are equally humane.

Slaughter

In developed countries, methods of slaughtering farm stock are regulated to minimize the animals' distress and pain. A common method is to stun the animals first with an electric shock, so that they feel no pain. Then their throats are cut and they bleed to death.

Just amazing!

MUSIC FOR MILK

FOLLOWING REPORTS THAT PLAYING MUSIC TO COWS INCREASES THEIR MILK YIELD, SOME FARMERS HAVE PROVIDED THEIR HERDS WITH RADIO SETS.

Paul Raymonde

***Pig carcasses** are blast-frozen to 0°C, then gutted and split using chain saws. After weighing the carcasses, electronic probes measure their meat and fat content. About 40 per cent of the edible part of the body is used for bacon. The rest is cut into fore-ends, middle gammon, loin and belly.*

Meat & Livestock Commission

PROCESSES FOR PRESERVATION

Over 1000 cans per minute can be processed by being heated in a large-capacity pressurized vessel at temperatures above 100°C

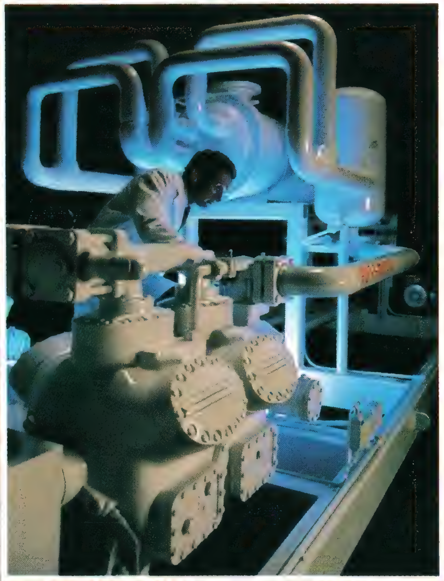


Image Bank

***Carcases are cooled** rapidly from 30°C to 10°C in a refrigerated unit (inset), then chilled more slowly to 1°C to prevent the meat from becoming tough. The chilled fresh meat is stored in a chiller at 0°C, 85–90 per cent humidity, with spacing between carcases to ensure good air circulation.*

THE RANGE OF FOODS available on supermarket shelves has grown rapidly during the last decade, but all forms of food preservation are still based on only two principles.

One is to destroy, deactivate or remove those elements that cause food to spoil. The other is to create conditions that inhibit these elements within the food.

Micro-organisms such as yeasts, moulds and bacteria account for much food spoilage. Heating can destroy organisms and deactivate enzymes – unfortunately, it can also cause unwelcome changes in colour, flavour, texture and nutritional value.

Heat treatment

Generally, heating food rapidly to a high temperature, maintaining the heat for a short time, then cooling it quickly – the high-short process – results in less loss of quality than

PRESERVING FOOD WITH GAMMA RAYS

Labat/Jerican Leatherhead Food Research Association

In an irradiation plant, food is carried on conveyor belts through an irradiation room where it is bombarded with gamma rays given off by cobalt 60 and caesium 137. The rays sterilize the food but the dosage is too low to make the food itself radioactive. Below right: irradiation strawberries; below left: untreated berries. Irradiation can extend the shelf life of fresh foods by retarding spoiling. Large-scale potato irradiation is practised in the USSR and Japan.

heat processes involving lower temperatures for longer times.

Sterilization is a relatively severe heat process which kills nearly all the micro-organisms in food. The commonest method of sterilizing food is to seal it in a container, which is then heated in a pressure vessel, or retort, by means of pressurized steam. Temperatures used are in the range 100–126.5°C for times ranging from 10–90 minutes, depending on the type of food and the size of the container.

Pasteurization

This is a more gentle process of preservation, which kills all food-poisoning organisms and micro-organisms, but only some of the organisms which make food go rotten. This makes food safe to eat, but it will deteriorate in a relatively short period. Pasteurized food is heated to temperatures below 100°C and maintained hot for specific periods of time, depending on the type of food.

Drying processes

Micro-organisms need moisture to survive and remain active, and moisture is also essential for many of the chemical changes that occur in foods. Drying removes most of the moisture, and this prevents the food from spoiling. Fruits, vegetables and some meat products are dried by heating in hot-air cabinets or tunnels.

Liquid foods, such as milk and coffee, are sprayed as a fine mist, which is mixed with heated air in a large drying chamber. The spray dries rapidly to form a fine powder, which may form lumps when spooned into hot liquid because the powder is so fine. To solve this problem, the spray-dried particles are re-wetted and brought into contact with each other so that they form clusters of larger-sized particles. When re-dried carefully, the clusters disperse and dissolve quickly in liquids.

Some foods, such as fruit juices and some fish and meat products, are damaged if heated strongly. Heat damage is minimized by heating these foods inside a vacuum cabinet, which enables the water to evaporate at lower temperatures.

Freeze-drying is a further development of vacuum drying. The food is frozen, then dried by being heated in a vacuum chamber. The ice changes directly to vapour, with no intermediate liquid stage. The result is a light porous solid, which keeps its original shape, picks up moisture rapidly when reconstituted and has a good colour, smell and flavour.

Concentration is another means of preserving liquid foods. If the proportion of soluble solids in acidic foods (such as jellies and jams) is increased to 65 per cent, a mild heat treatment gives increased preservation. Heat damage during concentration is minimized by boiling off the water at reduced pressures.

Freeze-concentration has been applied to fruit juices, coffee and tea extracts. After freezing the liquid food, ice crystals are separated from the remaining liquid. The partly concentrated liquid is frozen again, then the ice is removed, leaving a highly concentrated liquid with no heat damage.

Freezing inhibits the activity of micro-organisms and slows down chemical changes. Blast freezing is one of the fastest freezing processes. A blast of air cooled to a mean temperature of –30°C is usual.

***Milk is sterilized** in bulk, then put into pre-sterilized cartons which are quickly sealed under bacteria-free conditions.*

Image Bank

Just amazing!

DEEP-FROZEN SAILOR

FREEZING DOESN'T PRESERVE JUST VEGETABLES – A PERFECTLY PRESERVED SAILOR WAS UNEARTHED AFTER BEING BURIED IN ICY GROUND FOR 139 YEARS.

Paul Raymonde

HIGH PERFORMANCE EQUIPMENT

***Rowing simulators** use computer software to produce sound effects; the TV screen displays a pace boat to encourage greater efforts.*

Action Plus

SCIENCE AND TECHNOLOGY can help sportsmen in many direct ways. For example, carbon fibre golf club shafts can add 20 or 30 metres to the drive of an amateur golfer, without any extra effort or skill on his or her part.

Technology can help indirectly by systemizing traditional training methods through the use of machines.

Weight training machines come in many different forms. Simple pulley designs allow the user to work through a full range of movement, in relative safety. Most pulley machines allow you to exercise one muscle group at a time (single station), yet it is possible to group several single station units together to form a multi-gym.

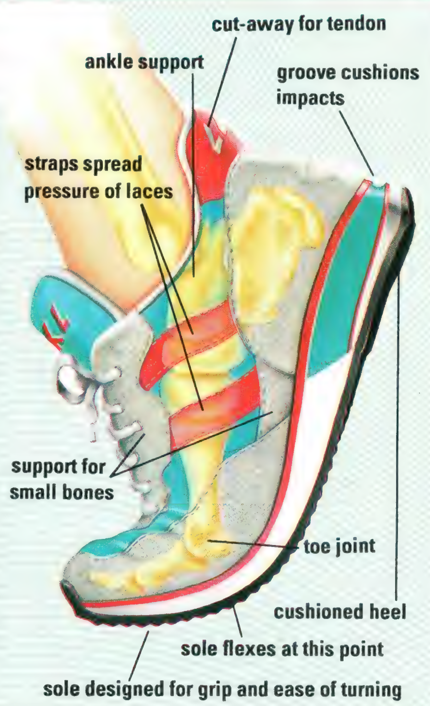
More sophisticated exercise equipment makes training more efficient through the inclusion of a non-uniform pulley which is known as a cam. It is known that muscles can produce more or less force according to their length, position, speed of contraction, type and the nature of the joints at which they act. Cam-based machines, such as Nautilus, try to take these factors

DESIGNING A RUNNING SHOE

The human foot is a very complex and delicate structure, with lots of small bones that can be forced out of place or broken if too much stress is placed on them. Sports shoe designers aim to take some of the load off the foot by matching the bending characteristics of their shoes to the bending characteristics of the human foot. They also suit the design to each specific sport.

This can't be done by studying the foot at rest – shoe designers need to know exactly how the foot hits the floor, the various positions taken up by the foot throughout the sequence of running actions and the exact relationship between the ankle and the foot.

The basic information is gathered by recording the running action of some typical runners using high speed filming techniques. Next, each part of the foot to be studied is labelled and transformed into a series of numbers that define each position on a digitizing table. When all this information has been gathered, it is fed into a Computer Aided Design (CAD) system and displayed on a VDU. Working on screen, the designer uses his knowledge and experience to produce the ideal shoe.



Chris Lyon

into account since the machine's cable or chain, as it runs over the cam, effectively ensures that the load the exerciser is overcoming is constantly changing. Cams match as closely as possible a muscle's 'strength curve' so that the training effect is maximized.

The most recent designs in exercise equipment have seen the introduction of hydraulic cylinders and even electro-magnets instead of weights to provide the resistance. Some of the latest machines also feature computer software, which allows them to be programmed with basic information about the user, before giving the appropriate training programme and sequence. Such machines also 'talk' to you, urging you to work harder!

Analyzing performance

Small differences of technique can yield big improvements in performance. The parts of the body that the coach wishes to study are labelled on a computer and the position at any given moment is recorded numerically. Another computer program then turns this information into a line diagram of all the movements; if necessary, variations in technique can be punched into the computer to see what effect they have on body position and predicted performance.

Artificial surfaces

Ordinary grass pitches and running tracks tend to turn to dust in the summer and to mud baths in the winter. For running and other sports, such as hockey, one solution is an artificial playing surface. The best types have a top layer of resilient polymer and are laid on an asphalt base incorporating drainage pipes. The polymer has sufficient 'give' to help prevent strains and jarred muscles; spikes do not damage it, so it can also be used for running tracks.

Using artificial surfaces for football pitches has not been successful, for several reasons. They resulted in an unacceptable number of injuries because, when a player swivelled, the foot tended to stay in the same position, putting enormous strains on the knee joint. Players also suffered skid burns and abrasions if they slipped or fell. In addition, the football itself tended to bounce very high on the artificial surface, which shifted the game away from passing and running and much more towards heading and volleying.

Computerized timing

A man with a stop watch cannot time accurately down to thousandths of a second – but this is comparatively easy using a computer system. The starting pistol or starting horn is fitted with a transducer which detects the sound made when the starter pulls the trigger. The transducer is connected by wire to the timing computer which starts to count immediately it receives the signal from the transducer.

At the finish the signal for the computer clock to stop is given by two parallel infrared beams in line with the finish. Two parallel beams six inches apart are used to prevent a stray arm or leg registering the finish: the whole body must pass through both beams before the clock is stopped. The time is printed out on a small slip of paper; it can also be displayed on the computer read-out and on a large read-out for the public.

Photo-finish camera

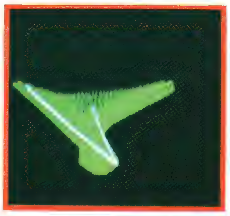
The photo-finish camera is vital in horse racing, track cycling and similar events, where lots of competitors may pass the winning post at almost the same moment.

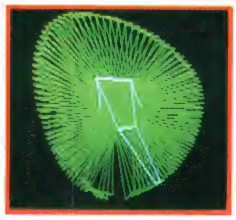
The camera is installed exactly in line with the winning post. A special lens with a large depth of field is used at the front of the camera, but instead of the normally circular aperture through which the light reaches the film, there is a narrow slit. Events are recorded in the order in which they happen, so the winner is the one in front on the film.

Photo-finish pictures record the time on a strip along the bottom of the picture.

Racecourse Technical Service

Two cameras take shots from different angles, which ensures that the winner can be picked out easily. The film is moved past the lens when the runners get near the finish.





***Three dimensional VDU diagram** of a gymnast on a gym horse breaks down the sequence of the athlete's movements.*

Loughborough University of Technology, Dept of Physical Education and Sports Science

__The best artificial playing__ surfaces are laid with a purpose-built machine that prepares the compound as it travels along, so eliminating seams. A laser head controls the surface level.

C Voight Söhne/Rekortan

POWER SPORT

CARBON BRAKES

STEPLESS GEARS

CERAMIC TURBOS

Colorsport

Colorsport

WINNING A MOTOR RACE, whether it's Formula 3 for beginners or Formula 1 for the title of World Champion, is a matter of getting a lot of engineering details exactly right, then blending them together into a winning design.

The regulations for each category of race lay down whether or not turbochargers are allowed, the maximum size of the engine, details of the bodywork and the overall maximum weight of each car. But within the scope of these regulations, the biggest influence on winning or losing is the amount of power that the engine produces. Engine output depends, among other things, on:

- Feeding the correct proportion of air and petrol into the engine, depending on the conditions
- Igniting the mixture at just the right moment
- Designing a combustion chamber in which the mixture burns well and so develops the maximum possible pressure (around 2,000 pounds per square inch) acting on the piston
- Enabling the exhaust gases to leave the cylinder as quickly and completely as possible, so leaving room for the maximum amount of fresh mixture to be drawn into the engine next time round.

Pumping losses

Until relatively recently the petrol/air mixture was simply sucked into the engines. But some engine power is used to suck the air in and pump the exhaust gases out of the engine. These losses are known as 'pumping losses'. To minimize this loss, many engines used in endurance racing and in rally cars now use a turbocharger.

This is an air pump powered by the energy in the escaping exhaust gases; it increases the pressure at which the petrol/air mixture enters the engines. The higher pressure ensures that the cylinders are completely full at the start of every power stroke, so a turbo racing engine produces more than twice as much power as an ordinary one. Winning Formula 1 engines have produced up to 1,200 horsepower.

Racing drivers have to keep 650 horsepower under control. Even in dry conditions, the cars go out of control; when it is wet, dangers are multiplied – especially at the start when the track is crowded.

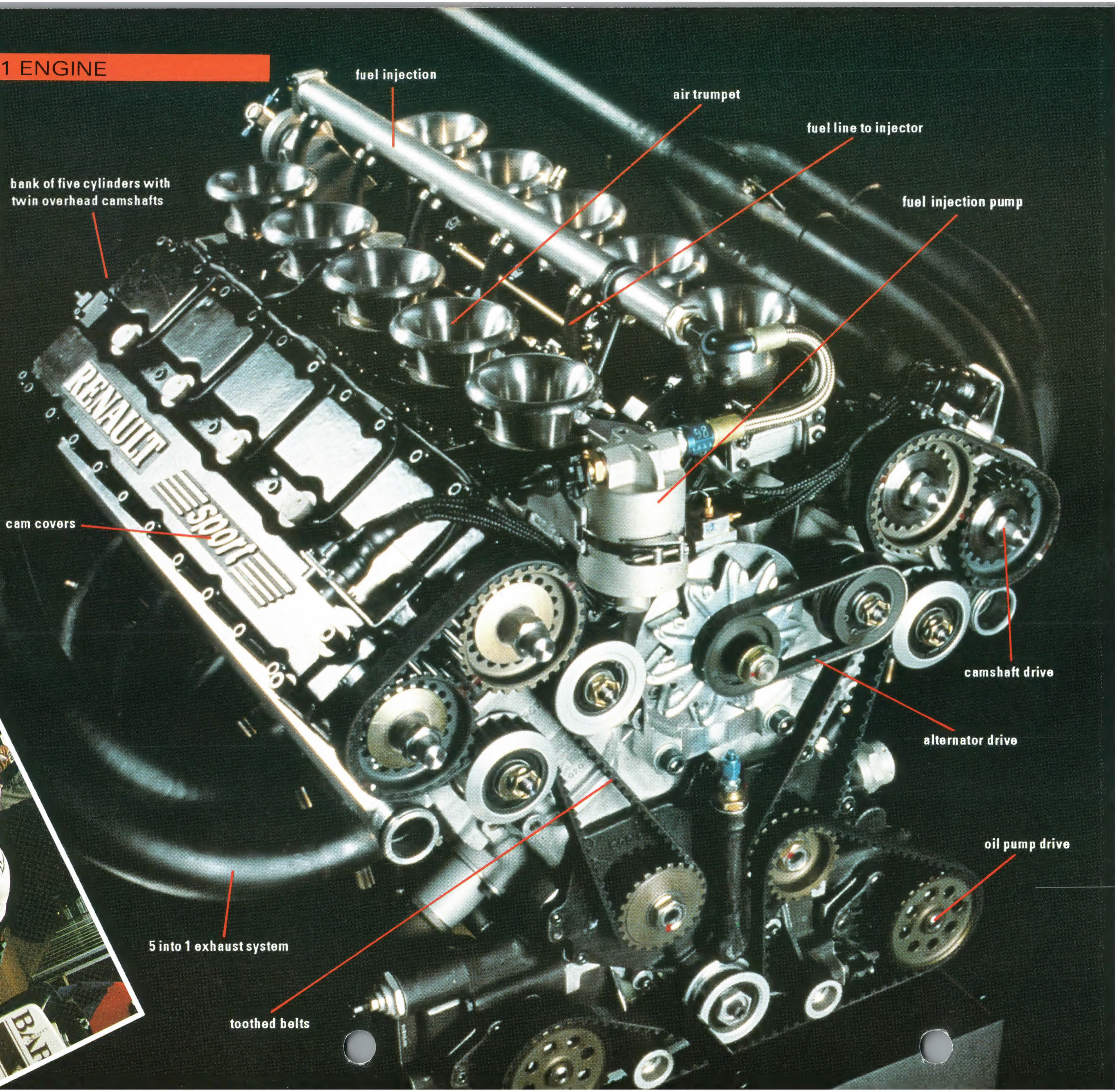
Ceramic turbos

Some of the latest racing cars are fitted with a turbocharger using a lightweight turbine made from ceramic rather than metallic material. This is similar to the porcelain used for making cups and saucers – but much, much stronger. As a result, the engine power builds up much more smoothly, which makes the cars much easier to drive in the heat of a race.

Microprocessor-controlled engine management systems also make life easier for racing drivers. One large electronic chip controls the pressure generated by the turbo, the fuel/air mixture and the timing

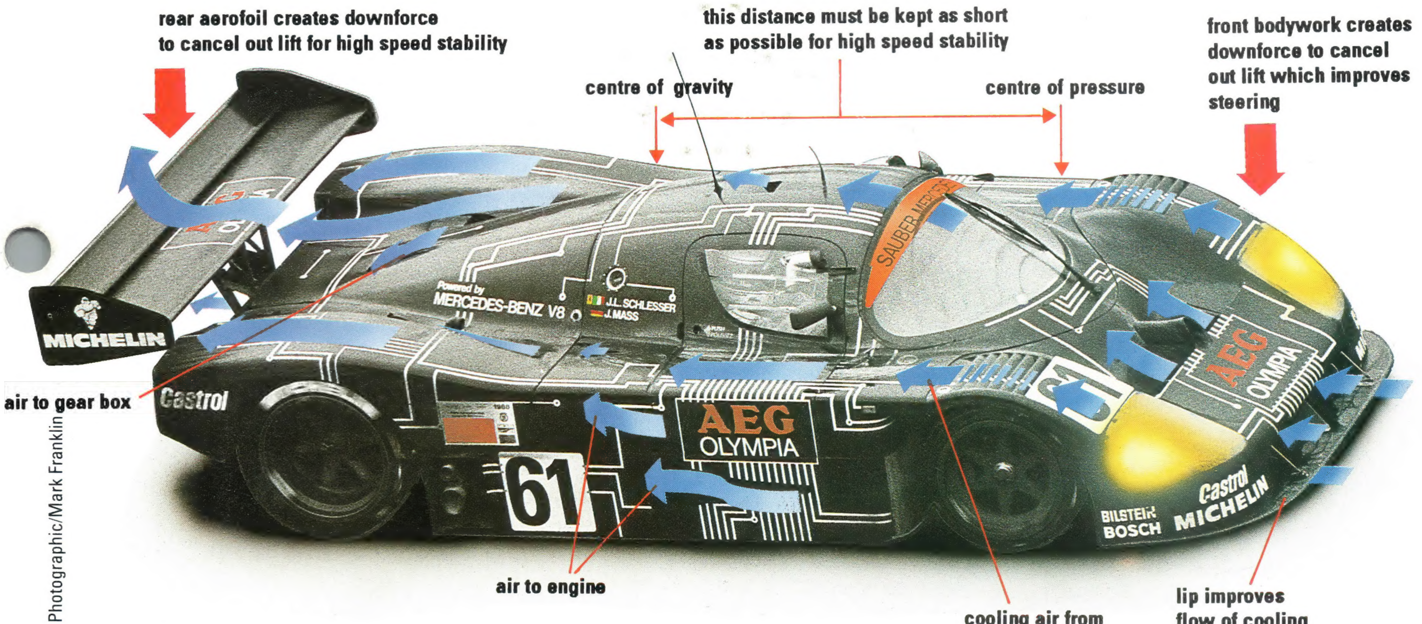
RENAULT V10 FORMULA 1 ENGINE

Renault have built a ten cylinder, Formula 1 engine that complies with the new regulations. It has two banks of five cylinders in a vee-formation to keep the engine short and so make it as easy as possible to fit into a car. Design and manufacture of the exhaust system is a major problem because it has to snake past the rear suspension and gearbox (inset below).



Renault

CSS Promotions



Air flow over a Group C endurance racer

of the spark that sets off the combustion process. Again, this smoothes out the power delivery so that when a driver puts his foot down, the engine responds without hesitation.

But there are problems with turbos, so at the end of the 1988 Grand Prix season, the small but powerful 1.5 litre turbo engines were banned. They have simply become too powerful for the drivers to control safely, and too expensive to design and build. In their place, Formula 1 engines will have 3.5 litres capacity and up to 12 cylinders instead of the four or six cylinders of the 1.5 litre engines. To extract the maximum power from these engines, designers are experimenting with 5-valve cylinder heads, and intake and exhaust systems that are carefully tuned to maximize gas flow, and variable-timing for the camshafts.

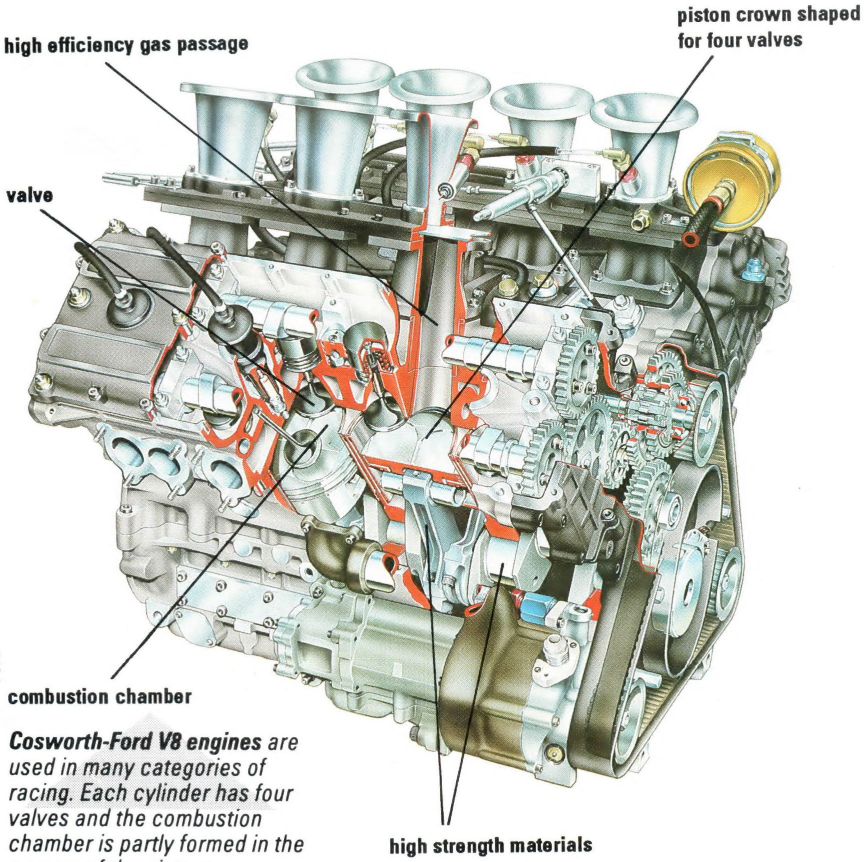
CAD methods

Computer-aided design methods enable racing car designers to work out exactly where strength is needed in engine, suspension and body components. With this knowledge, they can design lighter, stronger, faster cars.

***Formula 1 cars** must have open wheels but Group C long-distance cars are fitted with all-enveloping bodywork. This is designed in the wind-tunnel to cancel out lift and allow cooling air to reach brakes, driver and radiators.*

In the case of engine blocks, the strength is now built in using a network of carefully positioned ribs. This is much lighter than an engine block where the strength comes from walls with an even thickness. The thickness of body panels also varies between thinner central areas and thicker outside areas where the stresses are concentrated.

Racing car bodies are now shaped in a wind tunnel and made from composite materials developed in the aerospace industry. The most familiar composite material is glass-reinforced plastic (G.R.P.) or fibreglass. GRP has long been used in racing cars, but carbon fibre and Kevlar are now used instead of glass fibres for extra strength, extra chassis rigidity and better protection for the driver in a

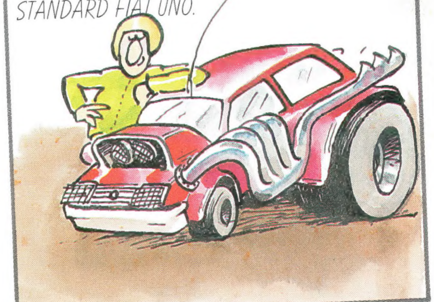


***Cosworth-Ford V8 engines** are used in many categories of racing. Each cylinder has four valves and the combustion chamber is partly formed in the crowns of the pistons.*

Just amazing!

VROOM VROOM!

THE 1989 FORMULA ONE FERRARI HAS ABOUT 650 HORSEPOWER AT THE BACK WHEELS – ABOUT 18 TIMES THE POWER AND 500 TIMES THE PRICE OF A STANDARD FIAT UNO.



Paul Raymonde

crash. This is all achieved in a body weighing less than 70kg.

A rigid chassis is important for racing cars because it helps the suspension work efficiently and so the car can corner faster. This brings down the lap time and is one factor that helps a driver to take his place on the winner's rostrum.

Racing car braking systems are also using aerospace technology. The brake disc itself is now made of carbon fibre at a cost of about £2,000 per disc – £8,000 per car. Carbon fibre absorbs much more heat than the conventional cast iron, but at the price of much faster wear on the brake pads. This only becomes critical in long distance racing where pads are often changed at the same time as tyres – perhaps every two hours throughout the race.

With good brakes, a driver can leave his braking to the last minute, and so pass drivers who have to brake before a corner. This outbraking manoeuvre wins many races, especially on narrow circuits where there is not enough space to overtake on corners.

Four wheel drive

The ever-increasing power produced by the latest racing and rallying cars is useful only if the tyres can transmit the power on to the road without causing the tyre to lose grip and skid. Wider and stickier tyres can help to deal with the power, but the best solution is four wheel drive. Here the engine power is shared between all four wheels, so each axle only has to transmit half the engine power.

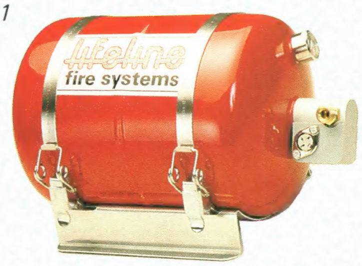
MINIMIZING THE RISKS

Fire is a major hazard for racing drivers in the event of a crash. To reduce the risk, all cars are fitted with safety valves in the petrol feed-pipes to prevent leaks if the pipes are accidentally cut. Also petrol tanks are made of rubber to minimize the chance of splitting.

Every car is fitted with an autommatic fire extinguisher system. In an impact, an electrical cap flies off a bottle of BCF fire extinguishing fluid. This turns to gas and blankets the engine bay. A separate container of BCF blankets the cockpit.

At the same time a supply of oxygen is fed into the driver's helmet. This replaces the oxygen consumed by the fire and gives a conscious driver precious seconds to free himself from the safety harness and get out of the car. An unconscious driver has to rely on the marshalls who should arrive on the scene within seconds.

1



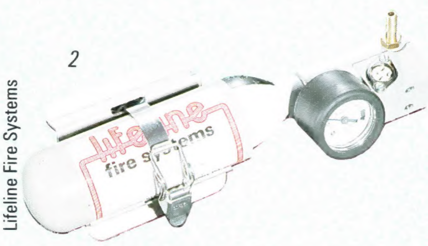
Lifeline Fire Systems

3

Allsport

1 Fire extinguisher tank containing BCF. 2 Oxygen bottle with gauge. 3 Driver clad in fireproof Nomex fabric, wearing safety helmet.

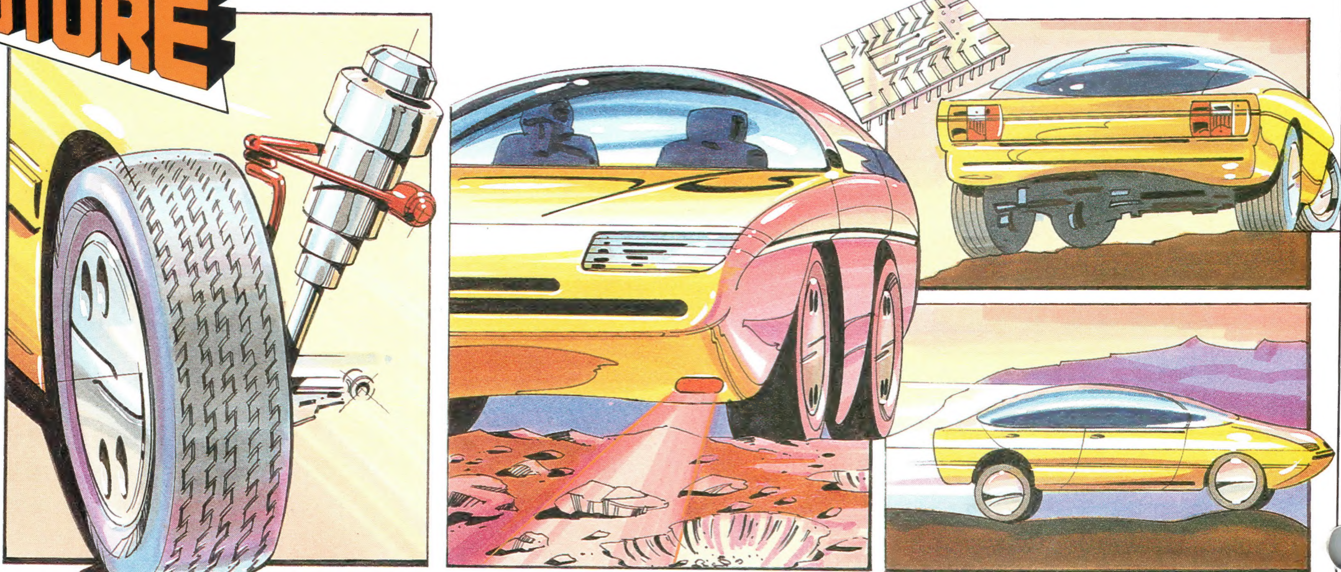
2



Lifeline Fire Systems

INTO THE FUTURE

ACTIVE SUSPENSION



▲ The fastest racing cars will be fitted with 'active suspension'. Instead of metal springs, the weight will be supported by quick-acting hydraulic jacks.

▲ Electronic height sensors using radar will be fitted in front of the wheels to detect bumps and potholes before the car passes over them.

▲ A micro-processor then works out how much each wheel has to be raised or lowered to keep the car on an even keel and so corner as fast as possible.

Joe Lawrence